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THE PROCEEDINGS

OF THE

SECOND

ALL-INDIA

SANITARY CONFERENCE

HELD AT

MADRAS

November 11th to 16th, 1912

VOLUME IV—ENGINEERING.



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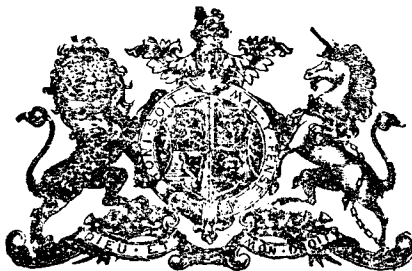


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Prefatory note.

This volume contains papers on ENGINEERING which were read at the Second All-India Sanitary Conference. It has not been found possible to reproduce all illustrations, plans, etc., attached to the various papers, and anyone specially interested should apply to the authors.

DESCRIPTION OF THE MADRAS CITY DRAINAGE WORKS INSPECTED BY MEMBERS OF THE SECOND ALL-INDIA SANITARY CONFERENCE.

The works inspected comprised:—(1) Special appliances used in the Drainage of Madras City. (2) Works completed. (3) Works in progress.

Special Appliances :—

Napier Park—

1. Silt-catcher.—This is an iron bucket fitted with a diaphragm designed to intercept sand used in washing pots and earth, sand and stone which get into the ordinary Indian house drains. A Silt-catcher as used in Madras will be shown and its effect in intercepting silt explained.

2. Silt and Storm-water Separator.—A typical Silt and Storm-water Separator such as those used in Madras on connections from side drains to sewers will be shown and its method of working explained.

3. Sewer Pipe Joint for Water-logged Ground.—Hassall joints have been used in Madras during the last year for the first time in Southern India. The method of making the joint will be demonstrated.

Law College Pumping Station—

4. Silt-raiser, Screens, etc.—These are typical of similar arrangements with which all the Madras Sewage Pumping Stations will be furnished.

Works Completed :—

1. Law College Pumping Station.—This is a typical small Steam Engine Sewage Pumping Station such as is proposed for the similar steam pumping stations still to be installed in Madras. At this station for the last six months has been pumped up to the Sewage Farm through a newly-laid cast-iron main the drainage of South Georgetown, which formerly ran into the sea and produced Kelly's Nuisance. The new pumping plant consists of three sets of Triple Expansion Worthington Pumping Engines furnished with steam by two Babcock and Wilcox Boilers. Each engine is capable of delivering 870 gallons of sewage per minute against a total head of 70 feet. The engines have been designed so that one engine shall be able to deal with the average dry weather flow, two engines working together with the maximum dry weather flow plus a small allowance for rainfall while the third engine is kept in reserve.

2. A new 16-inch Cast iron Main from the new Law College Pumping Station to the delivery main from Rayapuram Pumping Station.

3. The erection of new buildings and pumping plant at Rayapuram Pumping Station. The new pumping plant consists of two sets of Triple Expansion Worthington Pumping Engines with Babcock and Wilcox Boilers, each engine being capable of pumping 4,000 gallons of sewage per minute against a head of 50 feet.

4. The construction of an Open Channel at the Sewage Farm partly on piers and arches and partly on dwarf walls. This Channel supplies sewage to the whole farm through the new irrigation system.

5. The laying down of a system of pipes and channels for the complete Irrigation of the Sewage Farm. This consists of a system of underground pipes and surface channels by which sewage can be delivered to every part of the Farm. It has now been in operation for two years and by its means the Farm is irrigated efficiently.

Works in Progress—

1. Sewer Laying in every street in Tondiarpet. This has been completed except for a few of the deepest sewers.

2. The construction of three Pumping Stations A, B and C to deal with the drainage of the whole of Tondiarpet. Of these three, only "B" Pumping Station will be inspected. This is a typical Oil Engine and Centrifugal Pump Station. The new plant will consist of 3 sets of (30 B. H. P.) Campbell Oil Engines, each driving a 10-inch Gwynnes' Centrifugal Pump. At "B" Pumping Station will be raised all the sewage of Tondiarpet which will flow down the 2 feet 10 inches sewer to the Bell-mouth Chamber where it will join the sewage pumped from Georgetown.

3. The combined sewage will flow down the newly-constructed 4 feet 6 inches sewer to the head of the 5 feet 6 inches brick circular sewer where a second 4 feet 6 inches sewer will bring in the whole drainage of the Western and Southern areas of Madras. The 5 feet 6 inches sewer which is in course of construction will lead to the Farm Pumping Station. Thus the whole sewage from the three divisions in Madras will flow to the Sewage Farm Pumping Station through the 5 feet 6 inches sewer.

4. At the Farm Pumping Station the sinking of a double Rectangular Silt and Screening Pit is in progress. Here all the sewage of Madras will be raised into the head of the Open Channel whence it is distributed over the Sewage Farm.

J. W. MADELEY,

Special Engineer, Corporation of Madras.

Cost of Works inspected.

Completed Works.

Particulars.	Amount of sanctioned Estimates.	Actual Cost.
	Rs.	Rs.
Law College and Rayapuram Pumping Station Buildings ...	51,430	50,702
Do. do. do. do. do. Machinery ...	2,91,530	2,85,905
Alteration to Pumping Main and Sewers	15,750	15,718
Open Channel at Sewage Farm	92,000	85,005
Irrigating Farm on Broad Irrigation Methods ..	45,000	36,264
Taking up the 36-inch pipes at Sewage Farm and relaying as Pumping Main from Rayapuram Station.	43,400	38,500
The construction of 4 feet 6 inches and 5 feet 6 inches gravitation sewers to take the drainage of Georgetown and Tondiarpet to the Sewage Farm.	88,500	72,500
Total ...	6,27,610	5,84,594

Works in Progress.

Particulars.						Amount of sanctioned Estimates.	Value of Work done.
						Rs.	Rs.
Tondiarpet Drainage.							
Sewer Laying	...	...	...	...	...	6,32,635	2,97,700
House Connections	...	...	...	...	...	1,24,000	20,000
Pumping Stations including Engine House, Receiving Chambers, Office, Store and Tools-rooms, Latrine, Compound Wall, Machin- ery, etc.							
A. Station	...	...	...	...	...	55,815	45,000
B. do.	...	...	...	...	...	97,605	
C. do.	...	...	...	...	...	57,415	
Total						9,67,470	3,62,700

J. W. MADELEY,

Special Engineer, Corporation of Madras.

**ALL-INDIA SANITARY CONFERENCE—MADRAS—
NOVEMBER 1912.**

MADRAS CITY DRAINAGE WORKS.

BY

*J. W. Madeley, Esq., M. A., M. Inst. C. E., M. Am. Soc. C.E., etc., Special
Engineer, Corporation of Madras.*

1. For drainage purposes, Madras has been divided into a number of areas each draining to a pumping station where the sewage is raised and sent along on its journey to the Sewage Farm at the northern boundary of the Municipal area. The drains are admittedly in very bad condition, and works estimated to cost about 120 lakhs of rupees have been designed to give the city an up-to-date drainage system. Of these, works to the value of 25 lakhs are now in course of execution. The remainder will be taken up as the Corporation, with Government sanction, may decide.

Drainage Areas

2. The existing drainage system in Madras consists of a combination of open side drains, masonry drains and pipe sewers. All of these are intended to collect and convey to the pumping stations the "sullage" or soiled water which is discharged from the houses, but none of them perform their functions satisfactorily.

Existing system

The open drains of Madras are insanitary. The masonry drains are leaky and defective, and the old pumping stations are under powered and are not furnished with any means of removing silt or floating rubbish from the incoming liquid. Madras therefore affords an excellent opportunity for the study of the evils which result from a defective drainage system when applied to a large city. Some of these evils will now be described.

3. The side drains are open channels constructed along the two sides of the streets drained by them. In the first instance, they were doubtless earth ditches—and sewage is still flowing into hundreds of earth ditches—but in later years the ditch has been lined with masonry, usually of brickwork plastered with cement, and thus an impervious channel has been formed, which is a great improvement upon the original earth ditch. The disadvantages and dangers which attend their use in a populous town like Madras are well illustrated in those districts where such drains exist. The streets form a network of narrow roadways, each bounded on both sides by a continuous earth ditch full of liquid and semi-liquid putrifying sewage, which pollutes the air and gradually soaks away into the ground to foul the wells. Clouds of mosquitoes rise off the stagnant liquid which, in some cases, may be seen to have soaked up the walls of the mud huts to a height of 2 or 3 feet above the ground. People are living in these huts with sewage soaked walls; and sewage lies before their doors and under their windows. It would be difficult to devise anything more insanitary.

Evils of open side drains.

In Georgetown, a carefully thought out system of masonry side drains, delivering their sewage into underground sewers, has been installed. Here we see side drains at their best, laid as well as is possible in a flat city like Madras, but even here great faults are very apparent. For many hours of the day, the side drains contain long lengths of semi-stagnant sewage, and the most familiar smell in the denser parts of this city is that of gas rising from putrifying sewage. Sewage gas itself has not been found to contain normally disease germs in greater number than does ordinary air, but it acts poisonously and insidiously, it lowers vitality, and renders those who breathe it unhealthy, and unable to resist disease. Sewage gas should be confined to its proper place and liberated well over head, as will be done in the system of underground sewers now proposed.

House flies may be observed any day in Madras to settle on the wetted portion of side drains, and to fly directly thence and alight on passers-by, on children's eyes, and on the food on the stalls of the bazaars. There may be washings, and urine and even foecal matter in that sewage from a person suffering from enteric, tuberculosis, or cholera, and many diseases are known to be conveyed by flies. Nearly all exposed sewage in Madras may be seen to be the feeding or breeding place of countless mosquitoes: these insects are not only a pest, but are well known to be the great source of disease, and for this reason alone side drains should be abolished.

Every time it rains, quantities of sand and road metal get washed into the side drains, which are also used as receptacles for much garbage and rubbish that should go direct to the incinerators. It is almost impossible to avoid frequent blockage of the side drains, for it may take place only a few minutes after cleaning, and in consequence, a side drain, as a rule, contains long pools of more or less stagnant sewage.

The proper function of the side drains, is the conveyance of rainwater, and for this purpose, it is proposed that they should be modified as was done in Bombay when underground sewers were introduced into that city. The importance of educating people to object to the sight and smell of sewage is great for it affects their 'sanitary sense' and health. Side drains encourage insanitation; that is they make for dirt, smell and a high death-rate. All cities that have adopted good underground drainage, have shown a decrease in death-rate; the benefit has often been very immediate and marked.

Another grave fault resulting from open drains is the necessity for hand removal of excreta, which as carried out in Madras, is a filthy and degrading occupation employing a large amount of child and woman labour. Compared with the cleanly flush-out latrine and the water closet, it is indeed a barbarianism.

Old masonry drains.

4. In the old days, side drains delivered their sewage into what were called "masonry drains", built of brick work, approximately square in section and covered with granite stones. These masonry drains led the sewage into larger "main drains" of a similar pattern, which in turn discharged their contents at one of the pumping stations where the sewage was raised on to the numerous farms then in existence. But in addition a large proportion of the sewage flowed into the sea, or into the Cooum and various nullahs. These masonry drains still exist. They are most unsatisfactory as carriers of sewage; they are wrong in shape, they are nearly flat, and they are not watertight. As a consequence, the sewage flows slowly, and its filthy silt is deposited to fill up the waterway and to give off noxious gases inimical to health. Further, the liquid escapes into the subsoil and pollutes the underground water which feeds the wells.

Existing underground system.

With a drainage system consisting of open side drains and closed masonry drains of the kind described, the state of a large closely built up city like Madras was naturally most insanitary, and it was obvious that measures must be taken to make the city more healthy.

5. To remedy the insanitary conditions, a scheme of underground drainage was eventually decided upon after consultation of a large number of reports and schemes. Work was started and considerable sums had been spent when uneasiness began to dawn on the minds of the authorities that the work was not properly designed.

Under instruction from Government, Mr. William Hutton, the present Sanitary Engineer to Government, submitted a report on the works. He condemned the work that had been done as being designed on wrong principles and recommended that the works should be stopped as they then stood. His recommendations were accepted and the works thus continued at a stand still until the writer came out from England to design and carry out the waterworks and drainage works for the city of Madras.

Defects of existing underground drainage system.

6. In the first place silt and storm-water are freely admitted into the sewers, and, secondly, the sewers are laid so flat that the liquid portion of the sewage cannot flow sufficiently fast to carry the heavy solid matter with it. Being far too flat to deal with even the best sewage, the daily addition of silt from every house drain has caused the inevitable breakdown of the existing sewers to come quickly.

Silt should, as far as possible, be excluded from drains, sewers, and pumping stations. In the Madras sewers it is now allowed to enter freely. Silt in quantity, always and quickly, stops up every form of siphon—and a siphon is a necessity on every house drain, silt infallibly puts flat sewers right out of action, daily menaces with stoppage even the best graded sewers, wears out their invert, pours into the pumping wells every time it rains, cuts and wears away the interior of the

pumps, and commonly, when there is a storm, buries the suctions and stops the pumps just when they are most required.

Storm-water should also be excluded as far as possible from a sewage system like that of Madras, which is designed to deal only with the "dry weather flow." If rainwater in quantity is admitted to such a system, the flow is multiplied many times, the sewers are unable to deal with it, the pumps are overpowered, the whole system becomes congested, and liquid sewage overflows at manholes, at house connections, and often into the houses themselves.

There are many other serious defects in the existing sewerage system. The pipes and pumps are far too small to deal with the sewage. Arrangements at the pumping stations for screening the sewage and freeing it from silt are non-existent. The house connections are quite unsatisfactory, for they are continually becoming blocked and freely admit silt into the sewers. Arrangements for flushing the sewers have not been provided except only in Mylapore. Concrete pipes were largely used, and investigation shows that many of these are on the point of actual collapse.

Many details of the sewers were utterly wrong. No proper manholes were provided. Shafts were certainly built up but some two feet below the road surface, they were completely covered with granite slabs on the top of which earth and road metal were placed.

Not only was there no means of access to the shafts, but their very position was unknown.

Among other faults may be mentioned :—

1. Bringing house connections vertically down on to the top of sewers, thus causing a check in the flow and a solid deposit in the latter.
2. Connecting branch sewers to main sewers by laying a pipe at a high level into the main sewer manhole so that the liquid falls vertically splashing the sides and liberating noxious gas.
3. Manholes with flat bottoms not inverted in any way.
4. Want of proper means for flushing and ventilating sewers.
5. A large number of untrapped openings where side drains are connected to sewers.

7. The main defects of the existing underground drainage system may be summarised as follows :—

Summary of defects of the existing system.

(1) *House Drainage*.—Silt and storm-water are admitted in large quantities.

No provision has been made for receiving solid excreta.

(2) *House connections*.—are in many cases improperly connected to the sewers.

They are unprovided with cleaning arm and frequently become blocked.

(3) *Sewers*.—The gradients are too flat.

Except in one division no proper flushing arrangements are provided.

In some places the concrete pipes used are in a collapsing condition.

No proper manholes were originally provided.

The connection of a high level sewer to a low level sewer is made with a vertical drop resulting in splashing and interference with the flow of sewage in the main sewer.

In most cases the so-called manholes are flat bottomed without attempt to form an invert.

Insufficient ventilation is provided.

In many cases the sewers are too small to carry the sewage of the areas that they drain.

(4) *Pumping Stations*.—All the pumping stations except those completed within the last twelve months are unprovided with silt pits or screening arrangements.

The pumps and engines are both very inefficient.

Except in the two pumping stations completed within the last twelve months the pumps are unable to deal with the sewage which comes to them.

The cast iron main into which all the original pumps discharged is too small to deal with the sewage which would be pumped into it if the pumps were of sufficient power. It is unprovided with wash-outs and in its length of 9 miles has only two air valves.

Sewage Farm.—The irrigation of the sewage farm was so laid out that considerable areas of the farm could not be irrigated.

The main distribution pipe was too small, and the minor distributing channels were unable to convey sewage to a considerable area of the farm.

New works.

8. As already stated, these defective works were condemned by the Sanitary Engineer to the Government of Madras, and on his advice the whole of the work was stopped and the drainage staff disbanded. The writer's first drainage work, upon taking up his post as Special Engineer for the design and construction of Water-supply and Drainage for the City of Madras, was to make such alterations to the existing works as would enable them to be utilised to the greatest possible advantage.

Alterations to sewers.

9. In many cases the sewers were found to have been laid in scattered units. There were some sewers without manholes, unconnected with any outlet and destitute of house connections, which were brought into the existing system by building the manholes, making the house connections and laying a length of sewer.

Old brick drains were used as sewers for which they were unsuitable where the building of a short length of sewer was all that was required to divert the sewage and leave the old drains to perform the function of storm-water overflows, for which they are suitable. All works of this description, whose object is to ensure that the fullest benefit possible should be obtained from the existing drainage system, were put in hand.

Raising Manhole covers.

10. A gang of men was got together and the manholes throughout the City were raised to road level and fitted with cast iron covers.

Sewer cleaning.

11. When the manholes had been constructed and covers fixed, it was found that, owing to the exceedingly flat gradients at which the sewers had been laid, combined with the inefficient pumping power installed at most of the stations, and the free admission of silt and storm-water, the sewers had become choked. Complaints of nuisance and insanitary conditions caused by sewage overflow into yards and over road surfaces became numerous.

It was clear that the only method of keeping the defective sewerage system in fair working order was to clean the sewers systematically and continuously, if the breakdowns which had already occurred in many parts of the City were not to become universal. A special foreman was appointed and provided with a gang of men whose duties now are to clean the sewers regularly, to remove obstructions and generally to look after the upkeep of sewers. Under the new staff, sewer cleaning is done by a gang of coolies in each of the sections, into which the City is divided for drainage purposes. Another gang in each section is employed in removing obstructions and on other urgent work. The former gang works under a Superintendent and has an average strength of eight men consisting of a jointer and seven coolies. For emergency work there are four men under the divisional peon. The total number of sewer cleaning and emergency work coolies at present employed is 146.

Though this number is insufficient to keep the sewers free from deposit, nevertheless the benefit to the sewerage system has been most marked. In those

districts such as Periamet—where the system had failed, it has been placed in a workable condition, and is now maintained so as to cause no nuisance to the inhabitants. The consequence is that complaints from such districts have greatly diminished in number. One result of the sewer cleaning has been to confirm what has been said concerning side drain connections, *viz.*, that the free admission of storm-water carrying with it sand, stones, leaves, twigs and other solids, causes the sewers to be frequently obstructed in spite of regular cleaning.

12. The principle of using gravitation mains has been adopted as far as possible in the new system in preference to long pumping mains for the following reasons :— Drainage area,
pumping mains, etc.

- (1) Long pumping mains for sewage are very unsatisfactory on account of
 - (a) the deposit of silt in low places, and
 - (b) the accumulation of air in long lengths.

The combination of these two factors very greatly diminishes the carrying capacity of the pumping mains.

- (2) By the use of gravitation mains, the area that can be drained to any pumping station is greatly increased, for the gravitation main acts as a large intercepting sewer which, owing to the large volume of liquid flowing down it, can be laid at a flat gradient, and therefore can be carried a long distance before getting to a depth exceeding that where economical construction is possible.

By the use of gravitation mains resulting in the enlargement of drainage areas, the number of pumping stations required is greatly decreased. The pumps are larger and more efficient and thus the first cost and cost of upkeep are both much reduced.

- (3) Short pumping mains discharging into large gravitation mains have the advantage of allowing a cheap class of pump to be used satisfactorily. For instance, Suction Gas or Semi-Deisel oil engines driving centrifugal pumps can be used economically with gravitation mains where there is a constant head to pump against. But in the case of a long pumping main where the head is varying, especially at the time when the pumps are required to raise the maximum quantity of sewage, it is necessary to have a much more expensive type of pump, such as a Triple Expansion Steam Pump.
- (4) *Cost* : Gravitation mains themselves are very much cheaper than cast iron mains. The saving increases with the size of main. Generally speaking, with the size required for Madras, the cost of gravitation mains is about one quarter of the cost of cast iron mains.

13. When the drainage system is completed, there will be some fourteen pumping stations in Madras. Of these :— Number and type
of pumping stations.

Six will be Steam Driven Plunger Pumps discharging into the old cast iron pumping main.

Five will be Oil or Suction Gas Engines driving Centrifugal Pumps.

Two will be electrically driven Centrifugal Pumps.

One (Sewage Farm) will be Humphrey Pumps.

14. The principal new main drainage works which have been completed or are in course of execution. These works are all situated in the North of Madras and consist of :— New works executed.

- (1) Two new Pumping Stations for the Georgetown area which has a population of 142,000.
- (2) A pumping Main to convey the Georgetown sewage to the North.
- (3) Three Pumping Stations (A, B and C) to deal with the sewage of Tondiarpet, the Northern-most area of the city.

- (4) A complete system of sewers for the Tondiarpet area.
- (5) A Brick Sewer to carry the combined drainage of Georgetown and Tondiarpet to the Sewage Farm.
- (6) A new pumping station at the Sewage Farm.
- (7) An open channel to distribute the sewage over the Farm.
- (8) A complete system of Irrigation work for the Farm.

Of these :—

Nos. (1), (2), (7) and (8) are completed.

No. (3) Pumping Stations A, B and C are up to ground level and the pumping machinery has been ordered.

No. 6 (Sewage Farm Pumping Station) has been started and a contract has just been entered into for the delivery of Humphrey Pumps.

Nos. 4 and 5 (Sewerage of Tondiarpet and laying of a Brick Sewer) are nearly completed.

Works Nos. 1 and 2 comprise a completely new pumping station at the South end of Georgetown, the alteration and installation of completely new pumping plant at the existing Rayapuram station at the North of Georgetown, and the laying of two pumping mains 16 inches and 36 inches diameter respectively. These works were required for the drainage of Georgetown Section of Madras which had completely broken down. This area is drained by side drains which discharge into sewers and these in their turn conveyed the sullage to the Rayapuram Pumping Station at the Northern end of the area. The causes of the breakdown of the system were in the first instance the insufficient capacity of the pumps at Rayapuram to deal with the sewage which came to them, and secondly the inadequacy of the sewers to convey the sewage to the pumping stations. The consequence was overflow into the Buckingham Canal on the West, and the Harbour on the East, while in the centre the sewers overflowed into a large main drain which falling North and South from a central point discharged on to the foreshore at both ends. At the South it produced a nuisance commonly known as "Kelly's Scent Bottle" which affected the Government Secretariat in the Fort, and the mercantile community in the South-East of Georgetown. At the North end a similar nuisance was created which affected mainly the staff employed at Rayapuram Railway Station. To abolish these nuisances the following works have been executed :—

- (1) *A new Pumping Station* has been erected opposite the Law College at the South of Georgetown to pump to the Sewage Farm all the sewage previously flowing to the foreshore to produce Kelly's Nuisance.

Three pumping sets have been installed each capable of delivering 870 gallons of sewage per minute against a total head of 70 feet. These pumps are supplied with steam from two boilers each of which is capable of working any two engines when doing its maximum work.

The pumps are the well known Worthington Triple Expansion Direct Acting Pumping Engines. The boilers are of the tubular type manufactured by Messrs. Babcock and Wilcox. They are fitted with superheaters capable of giving 100 degrees of superheat above the temperature due to the pressure of the steam. Each pumping set is capable of dealing with the average dry weather flow *plus* a small allowance for rain. Two sets working together will be able to deal with the maximum flow anticipated and the third set is reserved as standbye.

The station is provided with collecting well, screen and silt pits and three pump wells; all sunk as wells, this being necessary on account of the large

amount of water encountered within a few feet of ground surface. The station itself rests upon a monolithic slab of concrete reinforced with steel rails.

- (2) *A 16-inch cast iron main 6,960 feet long*—which takes the sewage raised by the new pumps at the Law College Station and delivers it into the pumping main from Rayapuram Station. •
- (3) *Rayapuram Pumping Station*:—At this old station two new Worthington Triple Expansion Direct Acting Pumping Engines have been installed in place of two oil engines which were quite incapable of dealing with the sewage that came to them. Two new pumps have been fixed each capable of delivering 4,000 gallons of sewage per minute against a total head of 50 feet including suction head and friction.

The pumps have been connected with two existing Babcock and Wilcox boilers, in such a manner that each boiler can be used for working either engines or both engine, at will, and so that any engine or boiler can be cleaned or repaired without interfering with the working of the other engines and boilers.

The existing boilers have been thoroughly overhauled. They have been provided with superheaters, and a Green's Economiser has been fitted in a new brick chamber which has been constructed on a bye-pass to the existing flue.

Provision has been made for an additional engine, which will be fixed at some future time, if required.

At Rayapuram Station it was necessary to lower the floor of the building by 10 feet, and also to lower the bottom of each of the two pump wells by 5 feet. The floor was lowered in sections and concrete, reinforced with steel bars, was used for the new floor. It was a piece of work requiring extreme care because the new floor went below the footings of the pumping station walls. It is, therefore, very satisfactory to record that no accident and no crack of any kind occurred and no stoppage of pumping was necessary. Similarly the lowering of pump wells required great care because these wells are partly inside the main station building and the bottoms are 20 feet below floor level. In order to avoid damage, the sinking was done by means of cast iron caissons provided with diaphragms furnished with doors that could be rapidly closed in case of need. It is satisfactory to record that this work also was done without accident or damage of any kind, although it had to be carried out in running sand under a head of 12 feet of water.

By means of these two works, the lowering of the engine house floor and the deepening of the pump well—originally considered impossible without stopping the cost of building a new station • and the sinking of a new pump well—has been saved.

- (4) The laying of a 36-inch Pumping Main 3,900 feet long to convey the sewage raised at the Law College and Rayapuram Stations to the summit chamber in Tondiarpet where it is joined by the Tondiarpet sewage, and the combined sewage flows to the sewage farm down a new gravitation main varying in diameter from 4 feet 6 inches to 5 feet 6 inches.

The 36-inch pipes were obtained from the sewage farm where they had been laid to distribute the sewage. They were too small for this purpose and have been replaced by the open channel.

15. Tondiarpet has, for drainage purposes, been divided into three areas, *vis.*, A, B, and C, each to be drained to its own pumping station. A is the western, B the central, and C the eastern Station. Tondiarpet Sewerage

On arrival at Station A, the sewage draining to this station will be raised at once to the full height required, and will then flow by gravity along a 24-inch

cast iron main to the well of Pumping Station B. The sewage arriving at Station C will similarly be at once raised, and will then flow along an 18-inch gravitation main until it likewise reaches the wells at Station B.

On their way to B, the 24-inch iron pipe sewer from A and the 18 inch stoneware pipe sewer from C, will both be utilised as intercepting sewers: by this means, it has been possible to extend area B both east and west beyond its natural contour limits.

These two gravitation mains—utilised also as intercepting sewers—run at right angles to the contours, and become in consequence, the deepest sewers of the whole system. But the depth is well repaid. Every gallon of sewage they collect in the wings of B area, is saved being pumped a second time.

For, at B Station, all the sewage of areas, A, B and C is to be raised and sent on its way to the Open Channel. The sewage districts A and C will have been pumped twice, but that of B once only, when leaving Station B, hence it is obviously an advantage to make area B as large as possible.

The sewage of area B will of course drain to its own station, and Pumping Station B is to raise the whole sewage of South Tondiarpet into a brick sewer, 2 feet 10 inches in diameter, which will convey the sewage from the Pumping Station to the bell-mouthed junction chamber in Mannarswami Kovil Street. Into this chamber will be discharged also, all the sewage from Georgetown which is pumped from the Rayapuram and Law College Stations. The combined sewage will then flow by gravity along the 4 feet 6 inches diameter brick sewer, until it reaches the large Farm Pumping Station which is to be built at the head of the Open Channel.

Data on which
sewers have been
designed.

16. The following table gives for the three areas A, B and C, the acreages, populations in 1901, estimated future populations and estimated quantities of sewage:—

AREA.	DESIGNATION OF AREA.			Total.
	A	B	C	
Built up area in acres	127	259	153	539
Unbuilt up area in acres	133	65	20	218
Total area in acres	260	324	173	757

POPULATION.	DESIGNATION OF AREA.			Total.
	A	B	C	
Population as per Census of 1901	15,316	31,233	18,451	65,000
Increase of population over built up area taken at 30 per cent.	4,594	9,370	5,536	19,500
Future population of unbuilt up areas taken as 120.6 per acre	16,040	7,839	2,412	26,291
Total population for which the sewers have been designed	35,950	48,442	26,399	110,791
Gallons per minute.				
QUANTITY OF SEWAGE—				
Ultimate maximum rate of sewage flow to the stations, at 46.3 gallons per minute per 1,000 of population	1,665	2,243	1,222	5,130

The sewers for these areas have all been constructed in accordance with the principles set out in this paper. All the pipes have been laid except the 24 inch gravitation main from Pumping Station A to Pumping Station B which has been delayed, pending the laying of 36 inch Pumping Main from Rayapuram with the pipes taken up at the sewage Farm; for it is not until this was done that it was possible to take up the 24 inch main forming the old Pumping Main and relay it as a gravitation main from Station A to Station C.

17. The Pumping Stations A, B and C are brick buildings each arranged with three sets of Oil Engines driving Centrifugal Pumps. One set is capable of dealing with the average flow, two sets with the maximum flow and the third set being standby. Tondiarpet Pumping Stations A, B and C.

18. The following is a summary of the particulars of the engines and pumps which have been ordered:— Particulars of pumps provided.

	PUMPING STATION.		
	A	B	C
Makers of Engine	The Campbel Gas Engines Co.		
Makers of Pumps	Messrs. Gwynnes.		
Total number of units, each consisting of one engine and one pump	3	3	3
No. of units for maximum work	2	2	2
No. of standby units	1	1	1
Maximum pumping capacity of each unit in gallons per minute	500	2,100	600
Working head in feet	20	25	20
Size of pumps	5"	10"	6"
Efficiency for maximum $\frac{\text{Pump H. P.}}{\text{Brake H. P. of Engine}}$	50%	60%	50%
Water pump horse power	3.3	15.8	4.0
B. H. P. to drive pump	6.6	26.7	8.0
B. H. P. of engine using kerosine which would be required to give above B. H. P. on crude oil	7.3	29.4	8.8
B. H. P. of engines ordered	9½	30	9
Revolutions of engine per minute	280	220	280
Approximate No. of revolutions per minute of pump when pumping maximum quantity	1,040	360	860
Guaranteed consumption of liquid fuel in pints per pump H. P. hour	1.4	1.1	1.3

19. Each of the stations will be provided with a Venturi Meter which will be fixed on the delivery main outside the engine houses with a recorder inside the house. The meter is to be of a type specially adapted for measurement of sewage and will be provided with means of flushing the tubes and chambers and also of letting off the sewage gas which from time to time accumulates. A sewage Level and Pump Pressure Recording apparatus will also be fixed at each station, so arranged that one diagram shows continuously both the depth of the sewage in the pump wells below the centre of the pumps, and also the pressure above the centres of the pumps against which the pumps work. By means of these two meters, the quantity of sewage pumped and the head against which it is forced, that is to say, the work done by the engines, are recorded continuously. Venturi Meters.

20. The sewage coming to any of the stations first enters a receiving manhole whence it can be turned so as to pass through one or both of a pair of combined silt and screening chambers. These are circular brick wells with the bottoms formed as inverted cones. The inlet and outlet pipes are connected with these chambers at the top of the cone. The sewage entering by the inlet pipes loses its velocity in the large area presented by the pit, and the silt and other heavy materials in suspension drop to the bottom and are from time to time Silt pits and Screening chambers.

moved by a "silt raiser" of a design which has been patented by the writer. It consists of a fixed Tee pipe suspended over the centre of the silt pit. Inside this slides a movable pipe, the bottom end of which can be dropped on to the top of the silt, while the top end remains within the Tee pipe at a point below the branch. The branch leaves the pit some two or three feet below the top and leads to a settling basin at or about ground level. In operation the valves on the inlet and outlet pipes are closed. The chamber is filled from the pump discharge and the valve on the Tee pipe branch is opened. There is then a head of some 2 feet 6 inches tending to drive the liquid in the silt pit up the movable pipe and out through the Tee piece branch to the settling tank. The bottom of the movable pipe is kept close to the surface of the silt, and liquid in rushing up the pipe scours away the silt and carries it up and out along the branch settling basin, where the clear liquid is siphoned off and the deposited silt is subsequently shovelled into carts.

Screens.

21. Screens are fixed on the outlet side of the silt pit. They consist of light cages made of half round bar iron, well painted to preserve them from corrosion. When a cage is sufficiently charged with refuse it is raised above the top of the chamber by means of a light hand crane and swung over a cart, the flap door forming the bottom to the cage is then opened by releasing a catch and its contents dropped into the cart. The interior of the cage is then scraped down lightly with a rake, the door slammed up and the emptied cage let down again to its original position in the sewage flow.

Pump wells.

22. From the screening chambers the sewage flows to three pump suction wells each 6 feet in diameter. Each small well is connected separately to the outlet pipe from the silt and screening pits. This multiple well system is, for the ground encountered in Tondiarpet, much cheaper and more convenient than a single large well, for the small pits can be sunk without any timbering and with an ordinary amount of care, watertightness can be readily ensured under a head of 15 to 20 feet of water.

Well method of executing underground work.

23. It may be added here that wherever possible, all deep underground masonry work in Tondiarpet, such as screening chambers, silt pits and pump wells, has been constructed by means of wells sunk vertically downwards on account of the large amount of water brought freely to the excavation through the coarse sand beds that are encountered. At several pumping stations this quantity of water was estimated to be from 20,000 to 30,000 gallons per hour when nearing the bottom of the wells. In consequence of this flow and the considerable pressure—often over 20 feet of water—continual bursts of sand at the bottom took place whenever an attempt was made to keep down the water. To overcome this difficulty, the water was kept 10 to 12 feet deep by means of pumps and the excavation was got out by means of divers. By this method, blowings were obviated and the quantity of water that required pumping was considerably decreased. After the wells had been sunk to the required depth, the water was allowed to rise to its natural level and the bottom was sealed with cement concrete. The usual method of depositing the concrete was to place the bottom layer in gunny bags. Over this, concrete was deposited either by pouring through a long tube, or alternatively by means of buckets which were tipped when they reached the bottom. Both methods were equally effective when carefully done. As the water was standing at its normal level, there was no flow through the cement concrete which had every opportunity to set during the week for which it was left undisturbed. In no case was there anything but every small weeps of water although a head of water on the bottom of the well exceeding 20 feet was not unusual.

4 feet 6 inches Brick sewer.

24. The whole of the ultimate sewage of South Tondiarpet *plus* the whole of the sewage of Georgetown having a total population of about 280,000, will be delivered into the chamber forming the top end of the 4 feet 6 inches sewer. The combined sewage a maximum of about 15,000 gallons per minute, will for a distance of 5,800 feet, flow down this sewer to the large pumping station which is in course of construction at the Sewage Farm. About 1,000 feet from the pumping station, it will be joined by another 4 feet 6 inches brick sewer bringing the sewage of the whole of the western area of Madras. At the Sewage Farm itself, it will be joined by the sewage from the Southern area of Madras.

Almost the whole of the 4 feet 6 inches and 5 feet 6 inches sewers have been completed. They are both circular in section and there is nothing special in their construction. The 4 feet 6 inches sewer is built up to springing of concrete with a $4\frac{1}{2}$ inch lining of brick plastered internally with cement mortar. The arch consists of two rings of brick work. The 5 feet 6 inches sewer is of similar construction with three rings of brickwork in the arch. With the exception of internal cement plaster, the whole of the mortar used is combination mortar devised by the writer. It consists of cement, part, lime 1 part, surki, $1\frac{1}{2}$ parts and sand 6 parts, all measured by volume. This mortar has been found to reduce the cost in brickwork and concrete by Rs. 20 per 100 c. feet as compared with 1 to 3 cement mortar while the quality of the work is very nearly, if not quite, as good.

25. The whole of the sewage of Madras will, on arriving at the Sewage Farm Station, be passed through silt pits and screening chambers as in the case of the Pumping Stations A, B and C already described. These are also sunk as wells, but for convenience they will be square in shape, and instead of separate suction wells there will be a long suction trough into which will dip the suctions of the pumps. The pumps themselves will be of the Humphrey Gas type in which the explosion acts directly on the water without the intervention of any piston or gearing of any kind. This is the first time that this pump has been applied to the raising of sewage, and the results obtained will be of great interest. There will be eventually five pumps, three capable of delivering each 6,000 gallons per minute, and the remaining two 2,000 gallons each against a lift of 22 feet—suction lift 8 feet and delivery 14 feet. The pumps will be worked by suction gas generated in Semi-Bituminous plants of the suction pressure type, manufactured by the Power and Gas Corporation of Stockton-on-Tees. A small Reavell Air Compressor will be used for starting. A Centrifugal Pump will be provided for emptying the suction pit of any pump when repairs or other work below water level is necessary. This pump will also be used to prime the pumps when required. The Centrifugal Pump and Compressor will be driven by a small Gas Engine which will also drive the producer plant fan.

26. The *Open Channel* that has been constructed along the West side of the Sewage Farm begins at its Southern end with a receiving chamber 5 feet X 12 feet X 4 feet 9 inches. Open Channel.

This is separated from a gauging chamber (19 feet X 12 feet + 4 feet 9-inches) by a baffle wall. The sewage is delivered into the Receiving Chamber by the two pumping mains, and passing through openings in the baffle wall, flows as a quiet stream through the gauging chamber and over a weir to the Channel proper which is 6 feet 6 inches wide and 3 feet deep with a dished invert. The Channel has a gradient of 1 in 1000 from South end to North. With a depth of $2\frac{1}{2}$ feet, the calculated flow is 26,500 gallons with a velocity of 4.8 feet per second. At the Southern end, the Channel is ten feet above ground level. Here it is carried on brick piers 2 feet above ground level. Here it is carried on brick piers 2 feet thick and 10 feet 6 inches long resting on foundations of surki mortar concrete. The piers are connected by arches 9 feet thick, each having a span of 12 feet, a rise of 2 feet, and a width of 10 6 inches. There are 146 of these arches.

Where the floor of the channel is at ground level or slightly above, it is supported on two parallel brick walls running under the channel side walls. The space between the walls was filled with rammed sand and covered with concrete reinforced with $\frac{1}{4}$ inch steel rods.

Twenty wooden sluices of simple design have been provided to liberate the sewage along the length of the channel. Each sluice works in a masonry grove and is made of teak-wood stiffened with an iron handle which works through a slotted bar built into the masonry. This bar acts both as a guide and regulator for the handle and at the same time makes it impossible for any one to steal the door. An iron pin chained to the slotted bar will allow each sluice to be opened as much as desired according to the quantity of sewage to be discharged. On opening a sluice, the sewage flows down a masonry shoot formed on a pier end of the channel and passes into the irrigating system.

Sewage Farm Irrigation System.

27. The sewage from the channel is discharged into 18-inch concrete pipes laid at right angles to the channel in parallel lines 600 feet apart. These pipes are provided with manholes at every 200 feet from which sewage can be supplied either directly into open channels slightly above ground level running above and a few feet to the side of the 18 inch pipes, or by means of 9 inch under-ground pipes to similar open channels running parallel to the main 18-inch pipe and 200 feet on each side of it. From these open channels the sewage is turned over the surface of any part of the farm, and at the same time moving and other agricultural machines can be worked from side to side of the farm (about 1,500 feet) without encountering any obstacle due to channels or other irrigation works.

The masonry channel terminates at the northern boundary of the farm in an end which is provided with boards working in grooves ; by this arrangement the channel is kept as full as desired, and when there is an excess of sewage, the boards are removed as required and the excess allowed to discharge into the sea.

Sewage Farm.

28. The Sewage Farm is a strip of land about 1,500 feet wide extending for a distance of about 6,000 feet southwards from the northern boundary of Madras. It has an area of about 150 acres and until the beginning of the present year, it was let out to a farmer at a rent of Rs. 36,000 per annum. The farm has now been taken over and is worked by the Corporation. It is estimated that a net income of Rs. 50,000 per annum will be obtained when the farm is in thorough good working order. It is therefore undoubtedly one of the most successful farms in the world. It is noteworthy that there is no sub-soil and during the years for which the farm has been worked with sewage there has been no clogging up of sand of which the soil consists. It supplies a striking instance of what can be done in a climate like that of Madras by the application of sewage to a barren strip of sand. Hariali grass and cocoanut palms are the only produce of the farm. The farm deals with the whole of the sewage of Madras in dry weather, but in wet weather a considerable overflow takes place at the northern end of the farm, the liquid flows into the sea without causing any nuisance.

*General Scheme for drainage of Madras City.***Special conditions.**

29. Madras is a flat city 9 miles in length from north to south with an average width of 3 miles from east to west. The sub-soil consists of sand and clay. Through this sand, large quantities of water percolate and at all times of the year, water is encountered within a few feet from the ground surface. These conditions make it impossible to lay sewers at any great depth except at very great expense.

The question of constructing a large deep intercepting sewer running from south to north into which could gravitate the sewage from the different drainage areas was considered, but was discarded on account of the length of time that would take to execute, its high cost, and the considerable difficulties that would be encountered. The only method of constructing such a sewer would be by tunnelling with the assistance of compressed air to exclude the water. This work is necessarily slow, and it is costly on account of the plant and the nature of construction. Very little tunneling of this description has been done in India, and it would be necessary to employ European contractors with European foremen with the result that the cost would be very great.

Having decided that one large intercepting sewer was impracticable, the alternative of dividing the city into a number of drainage areas was adopted. These drainage areas are limited by the depths at which sewers can be laid, that is, by the nature of the ground and the quantity of water encountered.

In preparing the general scheme, the areas were first roughly worked out, in order to utilise the existing sewers as far as possible.

Where deep sewers would enable the areas to be extended, trial holes were excavated. These trial holes were 10 feet square and by their means the nature of the ground would be accurately determined and the quantity of water that would require pumping into trenches would be estimated very closely.

As a result of experience it has been found that in coarse water bearing sand such as that which forms the subsoil of Tondiarpet in the north, it is not practicable to go to a lower depth than _____ feet below mean sea level. In those areas where the subsoil is clay, or clay mixed with sand, the quantity of water is much less and in the proposed system sewers will be laid as much as _____ feet below mean sea level.

Principles and rules governing design.

The following are the principles and data upon which the new system has been designed :—

30. In the existing system, storm water is freely admitted. In the system to be adopted, it will be excluded as rigidly as possible. The reasons in favour of adopting the separate system for Madras are as follows :— Separate system.

- (1) The cost is very much less, if the storm water is excluded.

In a city like Madras where all sewage has to be pumped, both the initial cost and the cost of working a combined system would be very much greater than that of a separate system for the sewers would have to be designed to take the flow some thirty or forty times greater than the dry weather flow, and the pumps would have to raise a correspondingly increased quantity.

- (2) The disposal works will have a much more uniform quantity to deal with than a separate system and can be made much smaller.
- (3) The sewage is much more constant in character and is, therefore, more easily purified.
- (4) The variation in flow being smaller, the sewers can be laid at flatter gradients for it is the minimum flow that determines the grade of the sewers. Thus automatic flushing in dry weather is greatly reduced, and the quantity of water required is much less than in a combined system. This is an important point in Madras where water is scarce.
- (5) Sewers being smaller, arrangements for ventilating are much simplified.
- (6) The number of sewer connections is largely decreased, as no street gulleys are connected to them. This reduces the number of traps.

The following rules have been followed in laying out the system :—

- (1) The sizes of sewers in all cases have been fixed so as to be capable of carrying off in six hours, half the whole daily quantity of sewage of the anticipated population of 1960 of the areas drained by them, *plus* an allowance for rainfall equal to one-third of the maximum flow in some cases, where the nature of the district renders it desirable, the size of the sewers has been made somewhat larger than the above rule would give. The pipe sewers will be half full and the brick gravitation sewers three quarters full, when carrying this flow.

Thus the maximum carrying capacity of the pipe sewers will be at least $5\frac{1}{3}$ the estimated dry weather flow of 1960. While the brick gravitation mains will carry at least 3 times the same dry weather flow.

- (2) The mean dry weather flow for the sewers is taken as 25 gallons per head per day of the anticipated population of 1960.

- (3) The sewers have been laid out at gradients that will give self-cleansing velocities: the minimum gradients are:—

4" pipes	...	...	1 in 40	These gradients will be adopted only for those sewers—generally main sewers—where it is essential that the fall should be reduced to the minimum consistent with efficiency. All other sewers will be laid at steeper gradients up to the upper limit.
6" "	...	...	1 in 135	
9" "	...	...	1 in 230	
12" "	...	...	1 in 340	
15" "	...	...	1 in 460	
18" "	...	...	1 in 580	
21" "	...	...	1 in 720	
24" "	...	...	1 in 860	

The question of gradients is of very great importance and has been most carefully considered.

- (4) In some cases cast iron pipes are utilised as sewers. The main brick sewers have been designed of circular section, after carefully balancing the advantages of this section as compared with the oval section.
- (5) All manholes will be provided with cast iron covers. There will never be more than 300 feet between adjacent manholes.
- (6) Ventilation will be by means of shafts and perforated manhole covers. Where conditions render them necessary, special measures will be taken to secure adequate ventilation.
- (7) All silt will be excluded from the sewers, as far as possible, and special apparatus has been devised for this purpose.
- (8) Special arrangements are provided to exclude as much storm water as possible.
- (9) Arrangements are provided for flushing the heads of all sewers, and such special sections as require it.
- (10) Waste water from street fountains and washing places will be utilised for flushing both latrines and sewers.
- (11) Special types of flush-out and dry latrines have been designed for use by the poorer classes.
- (12) Paracherries will be drained by open drains connected to the sewers by special designed silt and storm water separators.
- (13) Night soil depôts have been provided for the introduction of night soil into the sewers at suitable points.
- (14) Where there is a considerable head or where the head varies considerably, direct acting Steam Engine Pumps will be employed. Centrifugal Pumps driven by Oil Engines, Suction Gas Engines Electric Motors will be employed where the lift is low and where the head is constant.
- (15) All sewage arriving at the stations, will be deprived of silt and screened before it reaches the pumps.
- (16) House drainage will be so carried out as to prevent the introduction into the sewers of silt and storm water.

Sewer gradients.

31. On account of the conditions prevailing in Madras, namely, a perfectly flat area with a high level sub-soil, it is of the greatest importance that the gradients of many of the sewers, more especially of the main sewers, should be the flattest that are consistent with efficiency. In the new work, all gradients are limited by the velocities which must be maintained in the sewers to keep them self-cleansing. The least allowable velocity, with the ordinary maximum flow, is fixed at $1\frac{1}{2}$ feet per second, which, under the conditions obtaining in Madras, means a velocity of about $2\frac{2}{3}$ feet per second in the pipes when flowing half full.

In order to make sure that the gradients chosen will insure a suitable velocity, a series of experiments has been carried out to determine the velocity of sewage, and its silt carrying capacity, in pipes sewers laid at the flattest gradients proposed. The result of these experiments was to prove that the gradients proposed are suitable, provided :--

- (1) That an excessive amount of silt be excluded from sewers.
- (2) That the heads of sewers and other points are adequately flushed.

Ventilation of Sewers.

32. The ventilation of sewers has been a subject of controversy and experiment for many years past in England ; some few believe in no ventilation at all advocating that all sewers be bottled up as much as possible. A second opinion is held by others, who believe in a little bottling up and a little ventilation : and it is in towns where such confused or undecided opinions are held, that one finds experiments in progress with the countless patent lamps, electric fans, "deodorizers," and chemical plants in manholes, etc.

Different systems.

A great body of opinion, however, has come to regard the system of tall columns and a right number of open street gratings, as being the most effective and practical method of ventilating sewers.

33. In Madras, the conditions of climate are helpful in sewer ventilation on the column and grating system, because the temperature is equable, varying slowly ; the normal directions of the wind are well defined, the city is flat, and the sewer air of one district, liberated from tall columns, will not sweep over higher building areas and trouble other districts. In hilly towns this is at times a considerable difficulty.

Surface inlets, and tall columns adopted for Madras.

Open grated covers will be put on the manholes where required, to act as air inlets to the sewers ; the outlets will be tall columns, 6 inches in diameter and usually from 20 to 30 feet high.

34. It has been found that in ventilating sewers nothing can be done by exact rule. The position of each column and every open grated cover must be considered and determined intelligently on its own merits. Proximity and height of houses, main directions of wind, the amounts of sunshine and shadow on each column, the levels of the ground, the paths likely to be taken by the sewer air, issuing from columns, all these must be thought of before fixing a single column or deciding the position of one tentative inlet. The inlets at road level should be put as far from houses as possible, so that they will do no harm if at times they act as outlets through adverse or unconsidered conditions : if found to be acting as an outlet, the grated cover can be replaced at once by a closed cover, and a new position tried.

Considerations which determine positions of surface inlets and of columns.

Open grated covers will not in Madras, be placed where the roadway is likely to be flooded by rainwater during the monsoon, for such water would rush straight down into the sewer ; but where an inlet is needed in a street liable to flooding, a pipe will be brought to the closed manhole from a raised inlet fixed at the road side.

The action of ventilating columns generally overcomes or at least counterbalances any adverse conditions produced by light winds : and when a high wind temporarily upsets some part of the normal ventilation, it must not be forgotten that there is also enormous dilution and diffusion of any gas escaping at street level on very windy days.

35. In special cases mica flaps will be used to prevent occasional efflux of sewer air from inlets ; but mica flaps get out of order rather easily and require frequent inspection. If in the least get-at-table, they are certain to be damaged by children and mischievous persons. They need careful placing.

Mica flap inlets will be used where necessary.

36. Ventilating columns, if high enough, require less care in placing than do inlets. The numbers of inlets and outlets required by a sewer system vary according to circumstances. Badly laid sewers, producing much gas, require more columns than do first class self-cleansing sewers. Cold climates reduce

Ventilating columns.

the amount of ventilation required, hot climates, however, are not believed to increase the number of columns needed, because the sun in hot countries can be depended on to heat the columns regularly and cause more rapid movement of the sewer air. Wind blowing normally across the top of a tube causes an up-draught inside it ; further, if a ventilation tube is heated by the sun, the air inside it becomes lighter bulk for bulk than that outside : the lighter air is then forced up the tube by the cooler and heavier air entering beneath from the sewer. It is largely owing to these two causes, wind and temperature differences, that sewer ventilating columns do their work. In Madras, there is a hot sun by day, and more or less breeze stirring as a rule and the column system may be expected to give at least ordinary satisfaction.

Patent methods of sewer ventilation used only for exceptional conditions.

37. Few, if any, patent methods of sewer ventilation have been a success on a large scale, and all are costly. Some of these systems have been used on a small scale for attempting to deal with especially foul and defective sewerage work, and there are sometimes cases where exceptional expense may be incurred by wealthy corporations, in order to use special means for the ventilation of sewers ; as in some very important street where high buildings make the column system difficult to use, or in a case like that of the Houses of Parliament, where a specially costly system of drainage and ventilation was permissible.

Of the patent methods of sewer ventilation, the lamp column is perhaps most pushed at the present time. While single lamps are useful at particular points, where, for some special reason, it is undesirable to fix ordinary columns, yet they cannot be recommended for general use throughout the city.

House Drainage and House Connections.

Water carriage should be gradually adopted,

38. There is little doubt that the water carriage system with underground drains and water closets will eventually be adopted in Madras. It has the following advantages amongst others :—

- (1) The excreta and urine, instead of polluting the air of houses and streets, goes at once to the sewer ; and in half a minute or so after deposition is safely on its way from human habitations.
- (2) The water closet is incomparably cleaner, nicer, and more sanitary to use for removing excreta than is any other known form of sanitary appliance.
- (3) An enormous amount of filthy hand scavenging is abolished. This work is very degrading, yet employs hundreds of men, women and children.
- (4) The great expenditure on conservancy of night-soil by bullock carts and coolies is not required. Night-soil depôts and trenching are done away with by using flushing latrines and water closets.

But the water carriage system will be introduced only gradually because:—

- (1) The expense of installing the system at once would be quite prohibitive. When water closet appliances are made as cheaply in India, as in England, there is little doubt that their use will become universal, even in the poorest houses, as now in England.
- (2) The mass of the inhabitants of Madras are not yet sufficiently educated in the principles of sanitation to understand the importance of working the system properly.

Water closets will be used in first class houses.

39. But wherever practicable, water closets should be installed in all hotels and clubs, in the houses of Europeans, and in those of all educated Indians who can afford them. The great cleanliness would be much appreciated and should create a general demand in the community for the European type of water carriage system. This is the experience of Bombay, and it will probably be the experience of Madras as the wealth of its people increases, bringing in its train a greater desire for comfort and a greater dislike of offensive nuisances. Of course it is absolutely essential that a water-supply, and flushing tanks of at

least two gallons capacity, should be installed wherever the water carriage system with water closets is put in.

40. Where water closets are installed in Madras the arrangements would be practically the same as are used in England, and generally in Europe and America. This system will be referred to as First class House Drainage. First class type of house drainage.

For existing houses the Corporation will provide the connection from the sewer to an intercepting siphon, to be fixed at the side of the road. The owner of the premises will bear the cost of the remainder of the work, which will have to be carried out in accordance with the Corporation bye-laws. In the case of new houses the whole cost of the connection will be borne by the owner.

41. In second class house drainage the ordinary open house drain is replaced by a pipe having properly trapped connections, and much trouble has been taken to design house drains and connections on these lines, suited to Madras. Second class type of house drainage.

The system may be applied to houses, which are intermediate between the first class houses, and the third class of houses in which live the bulk of the inhabitants of Madras.

As examples of cases to which the system is applicable, may be mentioned detached and semi-detached houses and bungalows, which are provided with gardens too small to allow the drainage to be dealt with inside the compounds without creating a nuisance.

42. It is anticipated that for years to come the houses in which first or second class drainage is used will be few in number. Therefore much thought has been given to the drainage of the ordinary small house of Madras. Third class house drainage.

43. In what follows, it will be convenient to consider the house drainage as made up of two parts:— House drains and house connections.

(1) *House drains* by which the sewage is delivered to the side of the street.

(2) *House connections* which convey the sewage from the edge of the street to the sewer.

44. In the poorer houses the drain is usually a brick-in-mortar channel of inferior construction, generally square in section, and frequently in such a bad state of repair, that solid matter is arrested and liquid matter soaks into the soft brickwork and the surrounding ground, thus producing highly insanitary conditions. In hundreds of cases there is on the premises a well which is almost certain to be found polluted by the soakage. These conditions should be radically altered, for they cause a high death-rate and much sickness. Existing house drains.

45. Most reluctantly the conclusion has been reached that underground pipe house drainage is not at present suitable for the majority of the houses of Madras, because:— Objections to covered pipe house drains for the majority of houses.

(1) It would mean a complete alteration of the existing drains of every house, a measure which would meet with great opposition from the occupiers.

(2) The expense of the connections would in many cases be very great in proportion to the value of the houses—cheap underground drainage for a third class house would cost about Rs. 200.

(3) Owing to the way in which the houses are built together, drainage to the back is impracticable. The covered pipe drain would, therefore, have to be led to the front right through the house. This would be not only difficult, but also dangerous and costly work, because of the likelihood of damage to houses caused by digging trenches close to, and, in many cases, under the house walls, for the foundations of the numerous small one storey houses are neither deep nor well constructed. Furthermore, it would be necessary to surround the pipes completely with 6 inches of good concrete, and this would add to the expense.

- (4) The success of underground house drainage depends directly on its intelligent use. Deleterious matters such as sand, ashes, and garbage, should not be admitted into the system. If materials such as those referred to were introduced, the traps would become choked, the floors of the houses would be flooded with sullage, and exceedingly insanitary conditions would be established. Every entrance to an underground pipe drain must be provided with a siphon; and the siphon must be protected by both a silt-catcher and a grating, to keep it from being blocked up by sand, ashes, rags, leaf plates, broken bits of bamboo, garbage, etc. These gratings and silt catchers would have to be fixed inside the house and would require attention which at present they would never get. Underground pipe drainage inside poor class houses, was tried and found to be a failure at Bombay. All the grids, and siphons, and the drains themselves, became quickly stopped up; and after vainly trying to get the system used more intelligently, all the underground house drainage had to be taken up; and open channels were substituted.

Third class house
drainage.

46. For these reasons the conclusion has been reluctantly reached, that underground pipe house drains would at present be quite impracticable in the majority of Madras houses.

Except where the owners are willing and able to put in a proper drainage system with all necessary traps and appliances, the writer is of opinion that house drainage by open drains should be adopted.

Such open drains entail the separate removal of solid excreta—a grave defect of the system—but, in almost all cases, the existing insanitary latrines can be converted at small cost into flush-out latrines, of a cheap but simple and sanitary type.

A separate rain water drain, discharging into the road side drain or ditch, will be required for every third class house. Some pains have been taken to devise arrangements by which one drain may be used to carry both the rain water and sewage, and yet ensure that excess rain water shall be excluded from the sewers. For the connection of side drains of Paracherries and minor roads where no sewers are provided, such an apparatus has been designed and experimented with, and has given satisfactory results.

But, while there would be no difficulty in adapting such arrangements to house connections in a town having a system of underground storm water drains, they are applicable to but few house connections in Madras, and provision for separate sewage and rain water drains must therefore be made.

Installation of
flush-out latrines and
W. Cs. in houses
with third class
drainage.

47. Although underground pipe drains from end to end of the closely built up houses are not recommended for the reasons given above, yet there will be no difficulty in fixing flushout latrines or water closets for those who desire them, and are willing to pay for them.

In fact every encouragement should be given to secure their adoption, for by this means the excreta and urine would be conveyed to the sewer at once, in a cleanly way, without any of the nuisance caused by the insanitary latrine now everywhere in use.

In such cases the flush-out latrine or water closet should be situated next to the road, so that a short length of cast iron pipe can be used to take the sewage direct to the sewer connection, without passing through the silt-catcher or sullage water siphon.

In many cases a cheap flush-out latrine of either a good plain cemented trough type, or of the better glazed pan type, can be substituted for the ordinary insanitary squatting wall with its accompanying smell, unsightliness, and hand scavenging.

A modern water closet of the European type can be put in with ease if desired, and is strongly recommended where there are upstairs latrines. In fact water closets in such cases should be compulsory.

48. To recapitulate: the plans of houses in Madras are so varied that it is impossible to prepare a few designs which will meet every case. The drainage of each house will have to receive separate consideration. Recapitulation.

House connections.

49. The sewer connections of houses provided with first and second class types of drainage will follow the usual European lines. Where necessary, separate rain-water drains will be laid to ensure the exclusion of the rain water from the sewer. Disconnecting chambers, modern intercepting siphon traps, air inlets, silt catchers, etc., will of course be provided. House connection for houses with first and second class types of drainage.

50. Much more important to Madras as a whole are the connections for houses having the third class type of drainage. A great deal of thought has been devoted to overcoming the defects of the present form of connection, and as a result, the method now to be described has been adopted. House connection for houses with third class type of drainage.

The type of connection for houses with open drains begins with a 4 inch pipe of stoneware or cast iron according to circumstances. Starting on the inside of the house wall where it is protected by a crating of special design, this pipe will convey the sewage to the silt catcher whence after being deprived of its silt it will pass through the siphon trap and into the 4 inch stoneware pipe which is fitted with a cleaning arm. The 4 inch pipe will be laid at a minimum gradient of 1 in 40, and will be connected with the sewer by an oblique branch, or by a suitable junction at a manhole, so that the flow from the connection will not interfere with the flow in the sewer, but will, rather, assist it.

51. In narrow streets where the depth of the sewer below ground is 6 feet or more, and in wide streets where the sewer is deep, a vertical down pipe will be used as shown. Vertical shafts.

The advantage of this vertical pipe is that it enables the connection to be laid as shallow as possible and thereby diminishes the considerable risk of damage to houses in the narrow streets that abound in Madras. At the top of the vertical pipe is a double access and test junction. The object of this junction is to facilitate cleaning and also to enable the test of the connection to be easily made by passing a stopper through the junction into the house connection. In many cases double junctions will be used so that two houses may be connected to the same vertical pipe. In a few cases as many as four houses may be connected to the same pipe by using two double junctions at different levels. A considerable saving is therefore effected by the adoption of these vertical down pipes.

52. Apparatus for excluding silt from the sewers is greatly needed. To insure that no silt, or only a negligible quantity, shall enter from the house drains, "silt catcher," or silt trap has been designed. This will be placed at the head of every house connection. Exclusion of silts.

The silt catcher consists of a steel bucket fixed in a masonry pit on the house drain. It is fitted with a diaphragm which passes across the bucket and extends 6 inches below the top of the bucket and 5 inches above. The sewage from the house drain flows over the rim of the bucket, strikes the diaphragm and passes in a slow stream under it. It rises still more slowly for the area of the outlet size is greater than that of the inlet size. The silt settles and accumulates at the bottom of the bucket while the liquid flows over the rim on its way to the siphon trap. If left to itself, the silt will gradually fill the bucket up to the bottom of the diaphragm. It should be emptied regularly, before it reaches this level but if neglected, the silt will accumulate on inlet side only until the inlet side is deeply silted up. Filtration of the liquid through the silt then becomes slow, and the incoming sewage backs up against the upper part of the diaphragm until it overflows through the tell-tale hole into the road or ditch, and indicates clearly to every one that the bucket is in urgent need of attention.

53. A stoppage of the pipe leading from the siphon to the sewer is not uncommon. When it occurs in the old type of house connection, it is necessary

to dig down to the pipe and break it open ; a proceeding which is both expensive and unsatisfactory, because it is difficult to make anything but a poor repair to the pipe, once it is broken. The road surface also is damaged.

The fault lies in the absence of a cleaning arm ; and a more up-to-date pattern of siphon trap provided with a cleaning arm would be a great improvement. As, however, there are no less than 15,000 siphons of the present type in stock, for which Rs. 64,000 was paid, a 35 degree junction is now inserted next to the siphon. This allows cleaning rods to be introduced and forms an effective clean arm. The stopper of the cleaning arm is sealed with weak mortar, to allow removal.

Latrines.

54. Two types of latrines have been evolved for use in Madras. In the superior type, there is a separate compartment with either European W.C. or an Indian squatting basin provided with siphon trap. This type of latrine will follow very much the lines of European latrine and need not be described in detail.

A cheaper form of latrine which is being used successfully both for public latrines and for factories, is of an automatic flushing type, the flush being provided either by a tipping bucket or by a siphonic flushing cistern. Separate compartments are provided because from numerous enquiries, it has been concluded that Indians appreciate privacy in these matters as much as Europeans, and it is important to encourage a sense of decency and a desire for good sanitation, especially among the class that use public latrines. The latrines are divided into compartments, all opening on to a common passage.

As the result of experiment, the sizes of the compartments have been fixed at 2 feet 6 inches square. The positions for taps, foot places, hoppers, and doors have also been determined by experiment. Short automatic swing-to doors of light teak boarding will give privacy. The tops of the doors will be 4 feet 9 inches high, but the doors themselves are only 3 feet 9 inches deep and 12 inches above the floor. Owing to the limits of the latrine corridor, no one see too much either over or beneath these doors except by unusual effort. On the other hand, it is easy to ascertain whether a compartment is occupied or not. The user on entering the latrine pushes open a pair of these small doors, which swing to gently behind him, he then finds his feet in position on the only standing room in the compartment. Facing him, but only 12 inches above floor level, is a small automatic water tap. While a person is using the latrine, this tap comfortably supports the right hand, leaving the left hand free to wash with. These washings fall on a narrow trough-like area, and cleanse it of urine ; they also keep clean and wet, that very steep part of the cemented latrine upper, on which the excreta falls, causing the deposit to slide downward at once into the 6 inch covered pipe channel which passes under each compartment. This arrangement prevents splashing, and also soiling of vertical parts difficult to clean. The user of the latrine having washed, stands up, steps into the passage, and the doors swing to again. The ablution tap closes itself automatically when the hand is taken from it. Heretofore brass taps have been used, but an effort is being made to obtain a cheap iron tap. In some cases the 6 inch stoneware pipe drain is flushed clean by an automatic siphonic cistern ; in other cases, by the waste water from the drinking fountain and washing place, which is in the open air, at one end of the building, but quite outside it. Before entering the drain, the waste water is passed through a silt-catcher to free it from silt which may have been used for cleaning pots, or brought on to the platform by the feet of those using it. From the silt-catcher the clear water passes into a tipping box, which discharges its contents almost instantaneously as soon as it is filled up to a predetermined point ; and rights itself again immediately the discharge is completed.

The frequency of tipping, and consequent flushing depends on the rate at which water is wasted at the washing place. This is generally sufficiently rapid at all hours of the day, but, if at any time more flushing is desirable, it can be secured by turning on one of the public taps for as long as may be necessary.

This would be done by the attendant who would be responsible for the cleanliness of a number of latrines.

55. The conservancy of night soil is a very insanitary, objectionable, and out of date method of removing faeces ; but a good many years must pass before night soil conservancy can be abolished in Madras. Excreta should of course be flushed into a sewer within a minute or two of deposition ; it then travels forward aided and enveloped by an allotted amount of water. Excreta collected in a cart should never be put directly into a sewer ; because it is not sufficiently liquid to flow easily ; in Madras there is a strong additional reason, for the scavenger when collecting, picks up with the excreta quantities of sand and silt, mingled with fragments of brick and mortar, sticks, stones, leaf plates ashes, tin cans, and other refuse, that should on no account be allowed to enter a sewer.

Night soil depôt.

In the depôt designed specially to deal with Madras night soil. The conservancy cart is backed up to one of the two receiving places, and is there tipped ; the excreta falls directly on to a cast iron grating, the surface of which is about 2 feet below ground level in order to prevent splashing, an abundant stream of water from a pendant flexible jet-piece is directed into the cart, which is sluiced clean ; the cart then moves away and the jet is directed on to the deposited excreta, quickly forcing it down through the $1\frac{1}{2}$ inch spaces between the bars. In this way, the excreta is at once separated from all large refuse such as sticks, cans, and leaf plates. This refuse is left on the bars, from which it can be removed easily by a proper rake, adapted to draw the rubbish up the masonry slope on to the floor level. It will then be lifted into a cart and sent to the destructor ; or a small single cell destructor could be easily attached to a depôt if desired. The excreta, as it is driven by the water jet through the grating, becomes broken up, mingled with water, and reduced more or less to a fairly thin consistency. In this state it falls through the grating into a smooth cemented shoot, which promptly delivers it through the division wall into what may be called the "flushing invert". This invert is a wide channel, having a narrow rounded bottom sloping quickly towards the inlet to the sewer. The lower portion of the invert bottom is occupied by a series of narrow cast iron gratings, of cross bars spaced $\frac{3}{4}$ of an inch apart ; the cemented invert is continued at a lower level, beneath this long narrow grating. When a considerable quantity of sluiced and screened night-soil has collected in the invert trough, and after, if needed, it has been stirred up (from the convenient standing platform provided) a self-closing valve is held open to give direct access into a sewer, and, at the same time, the flushing chamber is brought into action at the top end of the trough. The whole mass of excreta, in a liquid state, then pours into the sewer and is carried away. All refuse that escaped the large bars the receiving places will now be seen caught on the long narrow grating in the bottom of the cemented trough ; from which it can be readily drawn up by rake, on to the floor of the depôt.

A pit to intercept sand and silt is also provided, so that nothing but water and night soil may enter the sewer.

The carting floors will be of well dressed and grouted stone pitching which is sloped to the trough to facilitate cleansing ; the mixing floor will be of concrete, similarly sloped to assist washing. All corners are rounded, and every precaution has been taken in the design, to ensure sanitary conditions, and to reduce smell as much as possible in the night-soil depôts. A cast iron curb, imbedded in concrete, is provided for each receiving place, in order to prevent injury from cart wheels. The jets are to be controlled by small simple hand wheel valves. The supply pipes to jets and flushing tank are arranged so that no fouling is likely to occur to the water mains, under the existing conditions of intermittent supply, and if required an overhead storage tank can be included.

57.—Statement of estimated cost of works in course of execution and the value of works executed to November 1912.

Description of Works.				Estimated cost.	Value of work done to November 1912.	REMARKS.
				Rs.	Rs.	
MADRAS MAIN DRAINAGE.						
<i>Law College and Rayapuram Pumping Stations—</i>						
Buildings	...	...	...	52,830	52,700	Completed.
Machinery	...	...	...	2,91,530	2,67,000	Ditto.
Alterations to sewers and Pumping Mains				15,750	2,000	Ditto.
Open Channel at Sewage Farms, etc.	...			92,000	83,000	Ditto.
Rising Main from Rayapuram Pumping Station.				43,400	38,000	Nearly completed.
Remedial measures.	Sewers and Manholes	...	...	1,20,210	71,000	Ditto.
	Venturi Meters and Pressure Recorders	...		42,050	41,500	Completed.
	Additions to DeMellows Road Pumping Station.			19,000	9,000	Under construction.
	Alterations to existing Pumping Stations, Mains, Silt-pits and Screening Chambers.			23,000	9,000	Ditto.
	Circular Brick Sewers 3'-6", 4'-6" and 5'-6" diameter.			82,700	57,000	Nearly completed.
	Farm Pumping Station and pumping machinery.			3,02,000	12,000	Ordered.
	New Sewage Farm Irrigation System	...		44,500	36,000	Completed.
	16" Cast-iron Pipe from Law College to Rayapuram Pumping Station.			69,000	46,000	Ditto.
<i>Tondiarpet Drainage.</i>						
	Sewers, Manholes, and Overflows, etc.	...		6,32,635	2,97,700	Sewers nearly completed.
	House Connections	...	...	1,24,000	20,000	Under construction.
	Pumping Stations, A, B and C including buildings, machinery and acquisition of land.			2,20,685	54,300	Ditto.
	Contingencies	...	...	95,180	56,000	
	Miscellaneous works	...	...	28,000	15,800	
	Stores purchased but not used...	...		...	1,68,000	
	Inspection and Testing, etc., in England	...		...	26,000	
	Establishment	...	...	...	2,07,000	
Total				22,98,470	15,69,000	

**ALL-INDIA SANITARY CONFERENCE—MADRAS—
NOVEMBER, 1912.**

THE SIMLA HYDRO-ELECTRIC SCHEME.

BY

A. S. MONTGOMERY, ESQ.,

Sanitary Engineer to Government, Punjab.

The Hydro-Electric Scheme for Simla is being carried out for the dual purpose of supplying Electric light and energy to Simla and for furnishing energy for pumping water to augment the present supply.

The requisite power is being obtained by taking water out of a stream called the "Nauti," which is a tributary of the river Sutlej, and leading this water down an open concrete flume to the turbines and generators.

In order to divert the water of the "Nauti" into the flume, a weir has been constructed across the stream, with its crest 2 feet above the general bed level of the stream.

This weir is constructed of galvanized iron wire crates, averaging about 5 feet cube each, which are filled with boulders and are placed in a trench across the stream, about 15 feet below bed level.

On the boulder crates, the weir proper has been made, of concrete, faced with cut stone in cement and over this weir all floods will pass, while diverting the ordinary low water flow into the flume head. The gaugings of the Nauti show that at the driest time of the year, we may expect 28 cusecs flow and the flume has been designed accordingly. The low water flow will be diverted into an open channel behind a curtain wall, which is six inches higher than the crest of the weir and from this channel the water will flow into the intake chamber, which has been constructed with its walls well above high flood level.

As extraordinarily dangerous ground was met with in the hill side immediately below the intake chamber, it was here found necessary to tunnel straight through this into the hillside, and come out some 800 feet down stream clear of floods and bad ground. The concrete flume proper here commences. This flume is 4 feet by 2 feet and it winds along the hillside at a slope of 1 in 1,000 for about one mile, where it pierces through a promontory by a tunnel 7 feet by 6 feet cut out of the solid rock. This tunnel gave great trouble during construction, owing to the lack of skilled labour and the difficulty in getting down suitable drilling plant to the inaccessible spot where it is situated.

After emerging from this tunnel the flow continues in the open flume for about another mile, to a large reservoir to hold an 8 hours full working supply of 6½ million gallons, which has been constructed on a suitable spur.

The flume where it crosses a nullah called the "Jaori," passes through a reinforced concrete box girder of 30 feet clear span, resting on dry stone masonry abutments, and it is also covered over in places where it has been considered that the hillside above, was dangerous and likely to slip. Three settling tanks provided with suitable parabolic scour outlets, have been constructed at intervals along the flume line, to intercept all silt which might be brought down with the water and in the large storage reservoir also arrangements are provided for scouring out the silt.

Also at certain selected spots where the hillside permits, over-flows have been provided, which would come into action if the flume was damaged and blocked in any way.

As stated before the flume proper terminates in the storage reservoir and the water is thence led to the head of the penstock pipes, through a reinforced

concrete pipe 40 inches diameter which is buried in a track about 1,000 feet long. At the end of this reinforced concrete pipe the head stock chamber is constructed and out of this the six steel penstock pipes 16 inches diameter, lead down to the Power House, which is 540 feet below.

The Power House is designed in two complete halves, and also so arranged as to permit of an extension being added to it when required, but at present we are only installing three out of the total of 6 machines. Each half of the Power Station will contain three Pelton wheels direct coupled to a 3 phase alternator of 250 Kilowatt capacity, at a speed of 500 revolutions per minute, a voltage of 2,200 volts between phases and a frequency of 50 cycles per second. These alternators will be excited by two direct coupled exciters mounted on the ends of the shafts of the two centre machines for starting operations and also from a separate motor driven excitor set.

Power will be conveyed from each alternator to the Power House switch board, through 3 phase rubber cables and from the bus bars, power will be taken through oil switch panels, to a set of three 250 Kilowatt single phase step up, oil cooled, transformers, which will be situated in a separate transformer room, where the voltage will be stepped up to 15,000 volts.

The 15,000 volt side of the transformers will thence be taken through oil switches to the main transmission lines which lead straight to the main sub-station in Simla, and to the new pumping station at Chair. The transmission line to Simla is about 9 miles long, and the one to Chair is about 12 miles long, while a third line is also being laid from Simla to Chair, $7\frac{1}{2}$ miles long. This system of transmission lines, forming a triangle, has the merit of being able to send current round any two of them, should any one of the three be broken.

The Chaba-Simla and the Simla-Chair lines are supported on wooden structures, with short spans up to 1,500 feet, while the Chaba-Chair line is supported on steel structures, with spans averaging 1,000 feet, with a maximum of 3,500 feet. All the lines are composed of three No. 5 S. W. G. copper wires spaced four feet apart in a triangle and are protected at points where trouble from lightning is anticipated, by superimposed steel earth wires, and on spans over 2,500 feet, No. 3 S. W. G., Silicon Bronze wire is used.

The structures also carry the telephone wires, which run to all points where they are needed.

A reference to the map will show that the transmission lines terminate at the main sub-station on the north side of the Hill, below the Ridge, where the high voltage from the power station is stepped down by transformers from 15,000 to 2,300 volts. These transformers will then distribute the current to eight small sub-stations spread over Simla.

In these small sub-stations the current is again stepped down by transformers from 2,300 to 220 volts, the transformers being 3 phase oil cooled.

From these small sub-stations the current will be distributed throughout the station, by the low tension net work of cables which will be carried on Hamilton poles, which will supply current for street and house lighting.

Each pole will be fitted for street lighting with one or two Tungsten filament lamps, controlled at suitable spots by hand or automatic time switches. These lamps will be of 60 to 80 candle power. The work is well in hand on the whole scheme now and it is hoped to have the whole completed, so as to enable light and current to be supplied to Simla, by the 1st of May 1913.

Now to turn to the portion of the scheme known as the "Water Works Extension." For many years past the necessity of increasing the water supply of Simla has been recognised and all immediately available sources of supply having been drawn upon and taxed to their limit, it has been found necessary now to go much further a field for a copious permanent supply.

A reference to the map will show that water is to be obtained from two nullahs situated about 3,000 feet below Fagu village, on the Hindustan, Tibet Road, which is about 13 miles distant from Simla.

The water from the two Nullahs (known as "Bithu Ka Har" and "Pinjol Ka Har,") will be diverted into two gravity mains by low masonry dams, which have been constructed at suitable spots in the Nullahs, and the mains will be led down to a convenient place where a settling tank and Jewell gravity filters are being installed. The waters of these two Nullahs are of remarkable purity and will need little settling, but as the pumps which are being installed will have such a remarkably high lift and further the Jewell filters requiring a settled water to work on, it has been deemed advisable to put in a settling tank. The 2 Jewell filters which are being installed will have a capacity of 150,000 gallons in 18 hours or 140 gallons per minute each, are being supplied under a very high guarantee of purification by Messrs. Simpson and Co. who are the agents for this Firm.

The purification guaranteed is that if unfiltered water contains more than 3,000 bacteria per cubic centimeter a reduction of 97 per cent will be effected, and if less than 3,000, the filtered water will contain not more than 100 bacteria per cubic centimeter, and it is confidently anticipated that this will be worked up to.

The settled and filtered water will pass into a feed tank situated immediately above the pump house and will thence flow into two induction motor driven slow speed plunger pumps which will each be capable of delivering 140 gallons per minute through the two 5 inch steel rising mains, up to a small masonry reservoir situated close to the Hindustan-Tibet road, some 2,800 feet above.

This remarkably high lift is to be made in one stage and the makers of the pumps (Messrs. Simpson and Co.) guarantee this.

From this small receiving reservoir at the head of the rising main, the water will flow by gravity down ordinary 6" and 7" cast iron piping to the neck near Charabra whence it will flow down through a 4 inch steel main to a break pressure tank some 700 feet below, and will thence gravitate to Simla through the present mains.

The induction motors which will drive the slow speed plunger pumps at Chair, will be of Hunts Cascade 2 speed type, and they will be supplied with current at a pressure of 2,200 volts which will be stepped down from the transmission line voltage of 15,000 volts, through a bank of 3 single phase 120 K. W. transformers.

Interconnected with the Hydro-Electric Scheme will be the conversion of one of the present steam driven pumps, which supply Simla with water from the Cherot Nullah, into an electrically driven one. This will result in an enormous yearly saving in cost of fuel.

The power for this pump will be supplied at 2,200 volts, the 15,000 volt transmission line from Simla to Chair being tapped for the purpose, and the 15,000 volts stepped down to 2,200 through a 3 phase transformer.

The pump being installed will be of the Rees Returbo High Lift Turbine type working 2 in series with the driving motor placed in the centre, each pump being capable of delivering 380 gallons per minute to a head of 655 feet or 1,310 feet in all. The pump will run at a speed of 1,500 revolutions per minute and will be controlled by a standard mining type control pillar and auto-transformer starter.

The total cost of the Hydro-Electric portion of the work amounts to Rs. 13,20,264 while the water works extension portion of the project is Rs. 4,70,388.

Captain B. C. Battye, R.E., is now in sole charge of the work, and to him belongs the greatest credit for surmounting all difficulties, and bringing the work to the stage it has now reached and for designing and specifying for the complicated plant required.

**ALL-INDIA SANITARY CONFERENCE—MADRAS—
NOVEMBER 1912.**

SANITARY PROBLEMS IN MADRAS.

BY

W. Hutton, Esqr., A. M. I. C. E., Sanitary Engineer to Government, Madras.

The advance of sanitation in the Madras Presidency is necessarily slow owing to many causes, the chief of which are the reluctance of the responsible authorities to provide sufficient funds and the backward condition of the people in understanding sanitary methods.

Despite these adverse conditions we have accomplished in the Presidency a considerable number of works which admittedly have improved the health of the communities affected thereby.

I propose in this paper to refer generally to the different classes of works carried out, mentioning the particular difficulties encountered by us with the object of obtaining the views of delegates thereon.

It may be advisable for me to state here that the works referred to in the paper are more particularly those intended for towns and villages in *mofussil* areas.

Water-supply, Urban.—Of urban water supplies we have in use 19, and 6 are under construction.

Population.—The schemes for water supply projects of late years have been drawn up on the basis of the probable population 30 years hence. This probable population has been obtained from a population curve or diagram which has been prepared from the results of previous decennial censuses. As a rule this gives the probable population as about 30 per cent increase over the existing population.

Rate of supply.—The rate of supply per head is usually taken at 15 gallons for an ordinary *mofussil* town. It is doubtful whether this amount is sufficient, judging from the complaints received from many towns. These complaints are loudest in connection with street fountains which although numerous, fail to satisfy the people. We must not however lose sight of the fact that during the times of the maximum demand at street fountains the numerous house connections are also being used.

Waste of water.—Owing to want of sufficient provision in the original District Municipalities Act, powers for regulating consumption of water, waste of water and for fixing water meters were absent, and consequently the amount of water drawn off by house connections in towns increased out of all proportion to the quantity desirable. A new Act has been passed which gives sufficient powers for regulating wastage of water and for installing meters and charging for excess.

Attempts in the past have been made to fix the number of taps allowed in a private house in accordance with the rental value of the house and the taxes paid thereon, but practically no serious attempt has been made to fix meters or to make a charge for excess water. Consequently the amount of water wasted is relatively enormous owing to leaky taps and to taps left constantly open. I should prefer to fix a meter on every house connection at the municipal cost and to charge a rent for such meter to the owner or occupier of the house.

The house-holder should have as many taps as he requires. The free quantity of water to be supplied to each house should be fixed by a scale based

on the rental value and all water used for domestic purposes above this scale should be charged for per 1,000 gallons, the amount being read from the meter. The following is an example of a scale proposed for a *mofussil* town in this Presidency :—

Houses of the rental value per annum of Rupees.						Daily allowance in gallons.
100 and less	...	...	...	...	...	80
Above 100 up to 400	...	...	...	...	...	100
" 400 " 700	...	...	...	...	...	120
" 700 " 1,000	...	...	...	...	...	180
" 1,000 " 1,500	...	...	...	...	...	200
" 1,500 " 2,000	...	...	...	...	...	220
" 2,000 " 2,500	...	...	...	...	...	260
" 2,500 " 3,000	...	...	...	...	...	300
" 3,000 ...	...	...	...	...	...	350

The rate fixed for excess water varies from 8 to 12 annas per 1,000 gallons.

If water is required for non-domestic purposes, such as ærated waters manufacture or other trade purposes, the water so used should be measured by a special meter and charged at a rate approximately double that of the domestic rate.

The introduction of these rules rests with the Chairman and Municipal Councillors, and I regret to say that although their introduction and enforcement would mean a considerable revenue and would solve the problem of how to stop the waste of water, Municipal Councils hesitate in taking necessary action.

The principal sufferers from this inaction of Municipal Councils are the poorer people who use the public fountains and householders who live at higher elevations.

Direct pumping into water mains.—Our experience in Madras has shown that direct pumping into the main at the head-works without the intervention of a service reservoir is bad policy. Owing to the misuse of house connections in the town and the opening and shutting of such and of sluice valves on the distribution mains, it is impossible to maintain the requisite pressure in the main at the head-works pumping station. It is a fact that better results are obtained when the pumping engines pump the water into a service reservoir whence the supply to the town is distributed. When the wastage of water at house connections is stopped, the opening of taps on these connections would still result in such a sudden lowering of pressure in the main in the case of direct pumping, that damage to the pumping engines would result. When the first works in Madras were constructed, a service reservoir was omitted for financial reasons, but experience has shown that a service reservoir is absolutely necessary for the maintenance of a steady pressure, for the protection of the pumping plant and for the provision of a small storage. In the case of such a reservoir a capacity of 4 hours supply should suffice.

Water taps.—With regard to water taps for street fountains we have favoured for the last twelve years the type known as Tyler's patent automatic self-closing valve with lever handle. This type though expensive is durable. The principal defect is that the automatic self-closing part becomes inoperative after a time. This part consists of a gun metal plug which fits accurately into a casing and is intended to descend by its own weight on to the water orifice, thus closing it. Owing to the accurate fitting necessary for the gun metal plug and the fact that water generally contains a fine sediment, especially after river floods, this plug fails to drop, the mud in the water causing it to stick fast in its casing. When this occurs the tap becomes an ordinary spring loaded self-closing tap. It is true that the drop plug can be removed and washed, but as a rule this duty is not performed promptly so that the object of the invention is

defeated in actual practice. On the whole, however, these taps have been found the most satisfactory of all the taps tried in the Presidency. As the body is made of galvanised cast iron few thefts of the taps have occurred.

Improvement of village water-supply.—The insanitary state of the village water supply in the Madras Presidency has of late been receiving increased attention. Now that a considerable number of towns have received protected water supplies and the benefits derived from such protection in the reduction of cases of cholera and other water borne diseases have been admitted, it seems necessary to carry this protection further and to improve the sources of water supply of the villages adjacent to these towns, and also of the more important outlying villages.

A village water supply is usually derived from an irrigation channel direct, from a pond or tank or from wells. Little can be done in improving the quality of direct supply from an irrigation channel. It can be improved by digging a new tank or improving an old tank fed from the channel. This improvement is gained by storing the water so that the mud in it may settle to the bottom of the tank and the sun's rays may kill the germs contained therein. The next step is to conserve the tank by fencing it and by providing other means of drawing water than the present one of wading into it with the object of filling water vessels.

Drawing water from tanks.—The best way of drawing water from tanks is the provision of an engine and pump which can be used to fill a small reservoir, either itself provided with taps or supplying a short length of water main in the principal street with suitably placed public taps.

For the last six years an installation on this principle has been in use for an outlying part of the town of Salem. At this place there was a large square tank adjoining a main road, and the people were accustomed, after walking on this dusty road, to enter the water of the tank in order to fill water vessels. The contamination of the water by this means was very great. It was accordingly decided to erect an oil engine and pump, and to pump the water from the tank into a small masonry reservoir by the roadside. This reservoir was provided with 20 taps and the spill water therefrom was conducted into the roadside drain. Entrance to the tank was prevented by a wall surrounding it. The people who had formerly entered the tank were able more easily to draw water from the taps, this saving of labour being much appreciated and the quality of the water supply was much improved. This improvement in quality was borne out by the results of the cholera visitations. It was observed that the part of the town which used the water from this oil engine installation did not suffer from cholera, which was prevalent in the remaining parts of the town.

The cost of the 7-Brake Horse Power Oil engine and 3-inch centrifugal pump, masonry reservoir with 20 taps and a capacity of 5,775 gallons, surrounding platform and leading off drain, was Rs. 5,000. The annual cost of working, including repairs of plant, was Rs. 1,050. The quantity of water pumped daily was 56,000 gallons and the average lift was 35 feet.

Somewhat similar installations, if supplied to suitable village tanks, should give equal sanitary efficiency.

Tanks with draw off wells.—In villages which are unable to provide the cost and upkeep charges of a pumping installation, an arrangement of draw off wells connected to the tank by means of pipes can be substituted. In this arrangement the tank is fenced with suitable fencing, such as 5 lines of barbed wire, and 4 wells are sunk one on each side of the tank but outside the banks and the fencing. The bottom of each well is connected to the tank by means of a pipe, preferably of cast iron. The tank water enters these pipes about a foot above the bottom. The wells are provided either with bucket and pulley arrangement or with hand pumps. The provision of 4 wells to each tank enables one to be used separately by each section of the community. Plans illustrating the arrangement described can be shown.

Village wells.—Village wells are usually deficient in many sanitary requirements. They are generally unprovided with efficient platforms at ground level,

and it is rare to find one with a leading off drain. The inside of the steining is seldom plastered with cement above lowest summer water level. Contamination of the water in the well by soakage from the surrounding ground is usually the case.

The most important requirement of a well is an impervious platform around the parapet with a surrounding drain and a suitable length of leading off drain, so that no soakage of surface water can occur within 150 feet of the well, if of the usual depth of 20 to 30 feet.

The second most important requirement of a well is the drawing off arrangement. This arrangement should, if possible, be either a power-driven or a hand pump.

The third requirement is the covering of the well and the cementing of the steining above summer water level. In the case of wells where the draw off arrangement can only be the usual bucket and pulley, it is considered that the bucket and rope provided should be the property of the village authorities and should not be removed from the well. This arrangement should be encouraged instead of the usual arrangement by which each person brings his own bucket and rope thus contaminating the well.

A further improvement that can be effected in village wells is the provision of a power-driven or a hand pump to fill a reservoir provided with taps and located near the well. In lieu of this location the reservoir may be elevated so as to supply a main pipe laid in the village street and provided with suitable public fountains. Plans showing the improvements described can be shown to delegates.

Drainage.—The natural drainage of a village is a roadside ditch into which the sullage from houses is discharged. As the village increases in size and the nuisance from the roadside ditch becomes more evident, the necessity for developing that ditch into a masonry drain becomes apparent.

In a state of perfect repair this masonry drain is fairly satisfactory, but unfortunately such drains are seldom repaired and the task of keeping them daily cleansed and periodically repaired is generally neglected.

When the village becomes a town, under these conditions the nuisance from one street is conveyed by the open drains into the next and the inhabitants of the lower street have good reason to complain of the state of the drain in front of their houses. In order that these open drains may be effectual it is necessary that they should be constructed with good gradients, that they should be regularly and effectually cleansed and flushed, and that the sullage should be properly treated at the outfalls. If there were no silt in the sullage which enters these drains, and if the people did not put in them plantain leaves, straw and other materials which cause stagnation of sullage, such drains would act fairly well.

In actual practice we find that silt has to be removed from the drains daily and that the silt so removed is left on the roadside causing a nuisance. Even with good gradients the presence of plantain leaves and other materials which householders ought to burn, causes the sullage in the drains to pond up thus producing a nuisance. Granting that drains were free from objectionable floating matter such as leaves, road material sand and earth would be washed into them causing silting and stagnation.

It is impossible to obtain in actual practice efficient working conditions so that the provision of open drains for a town should be accepted, only if funds are not available for better means of drainage. The sight of sullage flowing in front of the doors of the inhabitants of a town is demoralising, and at the same time the presence of so much deleterious matter in the open favours the breeding of flies and mosquitoes and pollutes the atmosphere.

In constructing open drains we favour oval shaped masonry drains plastered with cement as this shape can be more easily cleaned than drains of triangular section made of stone slabs. It is difficult to clean the apex of such drains and the joints in the slabs become impregnated with objectionable matter. As an

additional argument in favour of oval shaped masonry drains it may be said that masonry drains are cheaper to construct than drains of stone slabs, except in the districts where the slabs are locally obtainable.

The sizes of oval shaped drains constructed by us are based on the amount of rainfall falling on their drainage areas, the amount taken being $\frac{1}{2}$ inch per hour for places where the annual rainfall is 40 inches and 1 inch per hour where the rainfall reaches 80 inches.

The gradients of these drains are fixed by those of the existing roadside drains.

Such open drains will therefore be most successful in towns where good gradients are available.

Closed sewers.—This type of drainage is necessary for towns which owing to their flat location cannot be drained by open drains. In such cases sectional pumping is necessary and a good example of this type may be observed in the City of Madras. By the use of closed sewers all the objections stated against open drains are removed. The disadvantages of closed sewers for *mofussil* towns are the deficiency of water supply for flushing, the difficulty of dealing with the rainfall which falls on roofs and courtyards and which unlike the home country is not distributed over the whole year, and the difficulty of providing satisfactory house connections owing to the peculiar construction of an Indian house and the habits of the people.

Want of water for flushing.—The deficiency in the piped water supply of *mofussil* towns for flushing sewers can be overcome by the provision of flush tanks filled either from existing wells or from new wells sunk near the tanks. Were municipal bye-laws strictly enforced and wastage of water stopped, there would be more than enough water available for the flushing of drains. Flush tanks can also be provided and filled from the spill water at most street fountains.

Rainfall.—Excess rainfall may be kept out of sewers by excluding all rainfall which falls on roads and similar areas and by limiting the amount taken by the house connection, the excess being surplussed into the roadside drain. The sewers should be made capacious enough to take a considerable quantity of rainfall at least equal to 6 times the dry weather flow. One advantage of taking this quantity is the periodical flushings obtained and the avoidance of excessive overflow of dilute sullage at house connections.

In order that the sewers may take a large quantity of rainfall, the lengths of 6-inch sewers should be limited to 300 feet and the usual length of 6-inch sewer beyond the primary length of 300 feet should be designed with 9-inch sewer pipes laid, however, at the gradient necessary for a 6-inch sewer pipe. Similarly the 9-inch sewer pipes should actually be laid as 12-inch pipes at the requisite gradient for 9-inch pipes. The larger sizes of sewer pipes should be similarly increased. The velocity of flow in these increased sizes of pipes is only slightly reduced below that obtainable from the smaller sizes and the increased capacity of the sewers allows a much larger quantity of rainfall to be carried off by the sewerage system and to be surplussed at suitable points on the line of sewers, leaving an amount equal to 3 times the dry weather flow to be pumped on to the sewage disposal works. The extra cost of laying larger sewers than are actually required for dealing with the sewage and a smaller quantity of rainfall is reasonable and only a small fraction of the total cost of the scheme.

House connections.—Owing to the peculiar construction of Indian houses with an open courtyard and to the use of sand and ashes for cleansing brass vessels, the amount of silt which is discharged into drains is excessive, necessitating either its removal before it enters the sewers or the laying of the sewers at steeper gradients than is customary in Europe. Judging from experience of the slackness of local authorities regarding cleansing, I doubt whether without immediate and constant European supervision the removal of this silt before it enters the sewers would be effected. I prefer to take all silts into the sewers, to give them suitable gradients and to rely on silt clearance and flushing of the sewers themselves.

With reference to the habits of the people it will be necessary to educate them in the necessity for sanitary improvements so that they may use without abuse the appliances provided. Instances are not unusual in the home country where the people have been familiar with these appliances for many years, of the misuse of closed drains. Besides having few or more of the disadvantages of open drains, a pipe sewerage system possesses the distinct advantage of permitting the conversion of all latrines into water carriage latrines, thus getting rid of the objectionable conservancy carts and trenches.

Opening up of congested areas.—A considerable sum of money is being expended in the Madras Presidency in opening up congested areas. The method often adopted of acquiring insanitary houses and forming new roads through congested areas in a town before provision has been made for the dispossessed people, is one which should be condemned. A plan of the town should be drawn up showing on it the proposed new roads and open spaces and the new roads and house sites in the area to be occupied by the dispossessed people. The new roads being made and houses erected, the people should only then be transferred from the congested areas. As the erection of the new houses by private owners is a slow process, it is advisable for Municipal Councils to erect the houses and to recover the amount from the occupiers. Our standard widths for new roads is, 1st class 40 feet, 2nd class 30 feet and sanitary lanes 10 feet wide. All houses should face one or other of the roads, and the sanitary lanes should divide the one house site from the other thus preventing back to back house sites.

In the sanitary lanes there should be either open drains, one on each side, or a closed pipe sewer, leaving a passage for a conservancy cart.

A type design showing the laying out of new house sites can be shown.

Markets.—While the grain, condiment and fruit stalls of markets in this Presidency are fairly satisfactory the construction and upkeep of the meat and fish stalls cannot be considered in any other way than very bad.

The first essential of a good market, *viz.*, cleanliness, is not aided by the class of people who deal in meat and fish nor by the public opinion of the more respectable classes who usually avoid these sections of a general market.

Municipal authorities, probably for similar reasons, are not sufficiently attentive to the cleansing of these meat and fish stalls and this remark also applies to important cities in India.

The only market in this Presidency which could be shown to visitors from the home country without preparation, is that at Ootacamund and the good state of this market is due not only to European supervision but to the fact that so many Europeans do their own shopping at it instead of leaving this important duty to inferior servants.

The difficulty of designing a good stall for the sale of meat is complicated by the custom of the butchers, who insist on sitting while serving a customer instead of standing as at home. Besides the usual provision of hooks for the meat, a chopping block is necessary and a platform for display. It is thought that instead of having this platform of masonry lined with white tiles, it would be better to provide an ordinary butcher's table with a thick wooden top. This table would be moveable so that it could be scraped, washed and placed in the sun daily. The stall would contain nothing but a seat, the wooden table and sufficient fixed hooks fastened either to a fixed stand or hung from the roof timbers, so that the stall could be easily cleared of furniture daily and sluiced out by a hose from the water main.

Such an arrangement would be satisfactory if the rules for cleanliness were strictly carried out, but as these rules would certainly be laxly observed, the problem is what is the best arrangement of a meat stall which will demand the minimum of attention to cleanliness.

In the case of a fish stall the requirements are an impervious platform for display of fresh fish and a sink for washing and gutting fish, the whole capable

of being sluiced by a hose before and after the day's operations. The platforms recommended are masonry ones lined with white tiles or wooden frames lined with zinc sheet.

In the case of both meat and fish stalls it should be the invariable rule that no storage over night in any lock up place or box in the stall should be permitted. Markets for meat and fresh fish should therefore, in the plains of India, be built open, the roof being supported on pillars and the open spaces enclosed with wire netting.

Public latrines.—A design for a public latrine which can be accepted as really satisfactory in actual practice, is one of the most important problems in sanitation. Such a design is only apparently possible where a sewerage system exists or where a system of automatic flushing for the latrine with septic tank and land treatment for the effluent can be arranged.

Large sums of money are annually expended in constructing public latrines, but it can be safely stated that excepting the two classes of water carriage latrines referred to above, no European would voluntarily use any of the dry class.

The question therefore is what is the least unsatisfactory of this type, and should any be constructed? Should not all important public latrines in places where no sewerage system exists, be constructed of the second type as recommended by Major Clemesha at the First Sanitary Conference in Bombay?

Education of the people in the necessity for sanitary improvements.—In the home country the success of sanitary methods could not be expected if the co-operation of the people had not been secured, and this has been brought about by the aid of articles in newspapers, lectures and instruction in schools, which have kept pace with or preceded the execution of sanitary schemes.

Simple health lectures should be given in schools in towns to both boys and girls on the necessity for cleanliness in the home and surroundings. These lectures should emphasise the need for pure water and warn against waste, protection of food from dust and flies, ventilation of the house, cleanliness of house drains and surroundings, destruction of refuse and cleanliness of clothing and the person.

In addition to this, municipal officials should interest themselves in the instruction of householders, especially the women, in similar subjects, this instruction serving a more important object than the prosecution of offenders. As a matter of fact prosecution of offenders against bye-laws is almost non-existent.

**ALL-INDIA SANITARY CONFERENCE—MADRAS—
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**SOME DIFFERENCES BETWEEN ENGLISH AND INDIAN SANI-
TARY ENGINEERING PRACTICE.**

BY

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Introductory.

The history of the progress of English sanitary engineering during the last 100 years has revealed clearly the unfortunate results that have often followed the assumption that a form of construction, a system of sanitation or a process of treatment which has been successful in one place must necessarily be equally suitable to the needs of some other locality, even within a short distance, and under apparently similar conditions.

When experience has shewn that such is the case within the limits of one small country, inhabited by persons of the same race, living under similar conditions of climate, the necessity is obvious of proceeding with caution in introducing methods of sanitation of European origin into India, in a tropical climate, and amidst a people whose habits and customs are as far as possible removed from those of the dwellers in European cities. It may in fact safely be assumed that many ideas framed on the basis of English experience will have to be discarded or considerably modified in applying them to Indian conditions.

That such modifications are actually necessary in many cases, no one who has experience of Indian sanitary engineering works is likely to deny, and as time goes on the development of Indian ideas on this subject will probably tend to become more markedly characteristic and distinctive.

In discussing this subject I will take the two main divisions of sanitary engineering separately, and will briefly refer to a few points in connection with the question as it affects both Indian water supplies and Indian drainage schemes.

Water Supply.

In his preliminary survey of a problem of urban water supply, the Sanitary Engineer in India will usually be impressed by several important points. He is limited in his proposals by the inadequate funds at his disposal; he probably finds the Municipality already more or less abundantly supplied from existing sources with water of a very questionable character, most of which would be condemned at sight in an English town or village; and he has to provide for a population apparently to some extent immune by descent from a long line of ancestors (who have consistently drunk water of similar quality), from the worst effects that would be experienced by a pure water drinking community if they were suddenly translated to an Indian village and made to exist on such water as is normally consumed there. How far immunity from water-borne disease can be acquired by heredity is a matter on which an engineer is hardly competent to express an opinion, but at all events a belief that such is the case is a source of some satisfaction to him when he is reduced to inadequate proposals by the financial exigencies of the situation.

Another point to be taken into consideration is the greater potency of the sun's rays in India as a germicidal agency than in more temperate countries. On the other hand the prevalence of cholera, and the consequently more

dangerously polluted condition of most of the natural sources of supply, are factors in the opposite direction.

The fore-going considerations will be sufficient to shew that an engineer responsible for preparing a water supply scheme for an ordinary Indian town, will have to depart somewhat widely from the lines on which an European installation would be designed. The first essential will be that the scheme should be a cheap one otherwise there will be no scheme at all. The source of the supply will frequently be one which could not be considered safe in a European country, the quantity of water given per head will be much less, whilst the greater purifying effect of the sun's rays and the partial immunity of the inhabitants to water-borne diseases may enable a simple form of purification to be considered fairly adequate.

A suitable source of supply for a town of anything up to 12,000 inhabitants in Lower Bengal, is frequently one or more large tanks situated either on the outskirts of the town or, possibly, if a suitable area can be found, in the centre. A catchment area of sufficient size will be enclosed and tanks excavated so as to be of the proper capacity. The greater part of the water supplied will be surface water drained off the catchment area during the rains and stored in the dry weather. There will be some infiltration of subsoil water at the end of the dry season, but in the compact alluvial clays of the Ganges and Brahmaputra deltas there is usually not much percolation either in or out of the tanks.

In districts where there is a sandy or porous subsoil, wells will probably be indicated as the best source of supply. If there is a permanently flowing river, that will naturally be chosen, and in places where there is a sandy river bed, dry on the surface in the hot weather, a filtration pipe or gallery under the bed is likely to be the most satisfactory arrangement. Artesian and sub-artesian conditions are not likely to be frequently found within the delta area and the prospects of such wells being found productive in the greater part of the Bengal Province are not very favourable.

With a tank or well supply it is usually necessary to cut down the quantity provided to the lowest possible limits. The quantities distributed per capita in Municipal supplies in Bengal are in some cases far less than would be considered possible in a European country, or so far as I know in any other civilised or partially civilised country. Generally speaking, my experience is that the following are approximately the quantities of water consumed daily in the mofussil towns by persons supplied through street standposts and private house-connections respectively.

- (a) Persons supplied through self-closing street standposts, 2 to 5 gallons a day each.
- (b) Persons supplied through metered private house connections, 15 to 25 gallons a day each.
- (c) Persons supplied through unmetered private house connections, 20 to 50 gallons per day each.

A person living in a house supplied through an unmetered connection consumes (or wastes) nearly ten times as much water as a person supplied through a standpost.

In India the engineer is generally employed in making the demand fit the supply instead of, as in Europe, supplying the demand. This can usually be done by arranging the works and controlling them properly. For example, supposing a Municipality of 10,000 inhabitants can afford a supply of 50,000 gallons a day for domestic purposes. The supply could be arranged thus—

9,500 persons supplied with 4 gallons per head through street standposts	...	...	...	38,000 gls. per diem.
500 persons supplied with 20 gls. per head through metered house connections	...	...	...	10,000 „ „
		Total	...	<u>48,000 „ „</u>

In this case not more than 25 private house connections could be allowed and automatic self-closing standposts would be necessary in the streets.

Some form of purification will nearly always be needed for a distributed water supply, whether the source of supply is a tank, river or well. My experience leads me to believe that slow sand filters are absolutely unsuited to the needs of a small Indian town. With proper management, slow sand filtration is undoubtedly on a large scale the most consistently satisfactory and reliable form of purification for ordinary polluted waters, such as a river water polluted by the sewage of towns higher up. Slow sand filters in small towns in India are however not generally well managed. They have usually been constructed as cheaply as possible, which means that the workmanship and materials are often not so good as they might be, and they are managed by men who are not highly paid or particularly intelligent and are incapable of carefully and scientifically controlling the system so as to give the best results. The filters are not properly scraped, the flow through them is allowed to vary within wide limits and they are abused in other ways.

Polluted subsoil water may also find its way into the under-drains or into the clear water well so that sometimes the water after filtration may be no better than, or even worse than the river water.

I consider that for the needs of an Indian town of anything less than 30,000 inhabitants, mechanical filters are generally much to be preferred. Of the two forms of the ordinary mechanical filters, gravity filters are much more reliable than pressure filters but the extra expense of the former process may make it impossible in a scheme where cost is of so much importance.

Where cheapness is the first consideration my opinion is that provided that an ordinary water can have a settlement and exposure to sunlight of at least 7 days, it will be moderately safe and potable if pumped directly through a mechanical pressure filter.

This would obviously not be sufficient in the case of any special form of contamination, such as water impregnated with soluble iron salts or containing excessive vegetable matter. Of the former type I have so far only come across one example in Bengal and the vegetable pollution of water in jhils and tanks in this country has never in my experience approached the condition of affairs in Equatorial Africa, where papyrus swamps and dense undergrowth causes the vegetable matter even in large lakes to be present in such large quantities as to necessitate some special form of treatment.

With regard to the works of distribution of water there is not much scope for difference in design from European systems. The concentration or the maximum demand into a few hours of the day appears to be more marked than in England, but it is difficult to speak definitely on the subject for few towns have a continuous supply. I have been in the habit of designing my mains so that the whole supply could be drawn off at the maximum rate of draught in 6 hours. This is proportionately more than the English allowance, but the actual provision per head in these towns is small and as the quantity per head given increases, the ratio of maximum rate of draught to average appears to diminish.

I have referred more to the smaller water works installations because it is in them that the departures from European methods are most conspicuous; as the size of the works increases the design approximates more nearly to that of similar works in England.

Drainage Schemes.

In the case of drainage schemes the differences between Indian and European requirements are more marked than in water works practice. In fact it may be safely said that the complete sewerage system with private connections to all houses is quite unsuitable to Indian towns. Exception may be made to this statement in regard to the central portion of Calcutta and Bombay, but even in the former city my own opinion is that the imitation of European methods has been carried too far.

Municipal drainage schemes may be divided into 4 classes. Commencing from the simplest form upwards, these are :—

- (a) A simple system of kutchā open surface water drains with possibly one or two main drains with masonry inverts.
- (b) A system of masonry open surface water drains.
- (c) A system of masonry open drains with one or two main intercepting sewers.
- (d) A complete sewerage system.

Of these (a), (b) and (c) cannot be compared with English practice at all; these types are usually only at best a compromise, and frequently unsatisfactory. Class (a) are generally works carried out primarily for anti-malarial purposes in scattered municipalities. Class (b) is the usual form of mofussil surface drainage scheme. Class (c) is a fairly obvious development of (b) in the larger towns and where circumstances make it necessary or desirable to have the main arterial drains underground. None of these systems need be discussed at length here. They are all types of work which are familiar to engineers responsible for preparing drainage schemes in this country.

It is in the case of sewerage schemes class (d) that there is most likelihood of an attempt being made to follow closely European examples.

It cannot I think be too clearly insisted upon that in India all private house connections and small branch drains should as far as possible be open, whenever excremental matter is not carried by them. In the ordinary Indian towns, even the larger ones, the majority of houses are of the most inferior form of construction, and for such buildings private water closets and closed branch connections are entirely out of place.

The combined system of drainage is extremely unsuitable to Indian conditions. The example of Calcutta is a case in point. On the other hand, if the open branches take all the stormwater and the sewers only a limited quantity, a difficulty obviously occurs at the points of junction of the branch drains and the sewers, in preventing much larger volumes of stormwater from reaching the sewers than they are capable of dealing with. Special arrangements are needed in such schemes at the street gulleys so that the dry weather flow up to a moderate number of dilutions is taken into the sewers and the surplus stormwater carried away by the main surface water drains. These latter would in most towns be open, but in some large cities might be shallow sewers. I have designed two schemes recently on this principle and I believe that the system will be found to work more satisfactorily than any other.

A special type of overflow gulley is required to make this arrangement work.

In some cases where a partial system of sewerage has been adopted [a sort of halfway scheme between classes (c) and (d)] circumstances may make it desirable to provide a modified form of septic tank at each of the large latrines and dumping depôts to ensure a partial liquification of the grosser solids before discharging into the sewers. I am at present introducing a drainage scheme into Gaya on this principle. It is obviously a method of disposal which would not be suitable for European cities.

With regard to the purification works at the outfalls of sewerage systems, there have hitherto been (comparatively speaking) so few installations on a large scale in my Province that I am not able to dogmatise. The main point to be noted is the greater efficiency of the septic tank than in European towns. On the other hand, the work performed by filters where these have been adopted has been rather disappointing. Whether some special form of filtration different from anything previously adopted will ultimately prove to be the solution of this problem, remains to be seen. Up to the present I am not aware of any urban purification works in India where results equal to the best European have been obtained.

Conclusion.

To enter into all the minor differences between English and Indian practice would require more space than I am justified in occupying. My own Indian experience has been mainly confined to Bengal, and I have only intended to refer to some of the distinctions which have characterised this class of work there, in the hope that my remarks may possibly be sufficient to initiate a discussion in which engineers having experience in other parts of India may express their views. There has been I think some tendency in the past, on the part of engineers whose experience has been mainly confined to European systems, to suppose that these can be transferred wholesale to Indian towns. Such an idea can only lead to unfortunate results. On the other hand without an intimate knowledge of the methods of sanitation in the more highly civilized countries, no progress is possible. A system of sanitary engineering suitable for India will in time be evolved which will be an imitation of such processes and works as may be suitably accepted, an adaptation of others, and on certain lines strike out in original directions.

Note on Sanitation in India.

Sanitation is a science but recently introduced into India and is therefore not in a very advanced state.

Some progress has been made with urban sanitation which presents no great difficulty in carrying out, but as it entails a considerable increase in the current rate of taxation in most towns, Government have to recognize that progress must be slow and measured by the strength and character of the public opinion they have to rely on in support of sanitary measures. In India, therefore, as elsewhere, the carrying out of sanitary works is now much more a question of available expenditure than of knowledge.

**Urban
Sanitation.**

Rural sanitation has made no progress, in fact it barely exists, and is a question of magnitude and difficulty. As a general rule the only way to improve rural sanitation is to remove the sites and construct new villages laid out on proper principles with protected water supplies.

**Rural
Sanitation.**

The origin of sanitation dates back some seventy-five years, when an Act was passed in England, and at a later date in India, about fifty years ago, for registering births and deaths. From the statistics thus made available, it was soon made evident that the annual death rate per thousand—the most convenient standard of expressing the general state of the public health—varied considerably in different localities and under different conditions, and the fact soon became established that the death rate depended broadly on two sets of circumstances—circumstances such as climate, clothing, feeding, local habits and customs, and others which cannot be brought under direct control by legislation, and must always be controlled by the individual; and circumstances such as conservancy, drainage, water supply, prevention of nuisances, etc., which can be brought under legislative control. It is estimated by sanitarians, that by the adoption of proper modes of life on the part of both individuals and communities a great number of existing diseases might be abolished and the annual death rate considerably reduced. Therefore, with this end in view, it has been found necessary to introduce sanitary legislation.

**Origin of
Sanitation.**

Modern sanitary legislation is based on the broad general principle that every member of a community is entitled to protection in regard to his health, which protection should be so exercised as not to interfere with the similar rights of others, nor be injurious to the community in general, and has therefore been introduced to provide for the co-operation and the combination of communities to carry out sanitary works in the general interest, requiring large outlays of capital which could not be compassed by individuals, and also to guard against the public health being endangered by the action of individuals.

**Sanitary
Legislation.**

The law has conferred certain well defined duties on Municipal Boards with regard to sanitary works and the powers necessary to enable them to carry out these duties. It has also provided an effective control in these matters and enabled such control to be exercised by the public and rate-payers as well as by Government. The passing of Sanitary laws, however,

**Duties of
Municipal
Boards.**

and the granting to a certain department the power to enforce such laws, will not ensure good public health unless the public at large supports those laws intelligently. In England very considerable trouble was experienced in introducing sanitary measures. Even at the present day numbers of convictions take place for neglect of regulations and for positive nuisances in large towns, and the people still require supervision and at times coercion to make them attend to their own best interests. In India, therefore, where the habits and prejudices of the people, their religious observances and apprehensions, and other conditions are so widely different to what obtain in England, and Europe generally, it is no wonder that sanitary reforms and works are looked upon with suspicion and distrust, and unless some palpable benefit can be realized and appreciated by the people, the introduction and carrying out of such reforms and works is a matter of much difficulty and opposition.

**Preparation
of
Sanitary
Projects.**

The majority of Municipal Boards in India are dependent on the advice of Government Officials in sanitary matters, as they have with a few exceptions, no independent professional agency to assist them in the preparation of sanitary projects. In such cases, the projects are prepared by the Sanitary Engineers to the Local Governments, and after approval by the Sanitary Boards, submitted to the Local Governments for sanction. To make these Municipal Boards fully acquainted with the facts for which they are responsible and to stimulate them to greater efforts, it is necessary that clear periodical statements of the vital statistics of the locality should be supplied, in the fullest detail. Programmes of sanitary works should also be prepared under the chief heads of—

1. Conservancy, including the removal of refuse.
2. Filling up of insanitary tanks and cesspools.
3. Latrine accommodation and public urinals.
4. Drainage.
5. Water Supply.
6. The improvement of overcrowded areas and of buildings with defective lighting and ventilation.

These projects of sanitation should be carefully prepared with reference to local circumstances and the resources of the Boards concerned.

Conservancy.

The neatness and cleanliness of the appearance of a town depend on the methods in which the conservancy is carried out and on the way in which rubbish is collected by the householders for removal by Municipal carts. In many cities the rubbish is freely shot out into the street at certain hours, and the provision of the Municipal Act, with regard to the establishment of proper depots for the deposit of rubbish by house occupiers, has become a dead letter.

In most cases, all practical purposes will be met by providing that rubbish is to be stored outside the premises at certain hours in baskets or boxes of suitable size which require simply to be entered into carts, which would be sent round once or twice daily for purposes of removal to either incinerators or depôts outside the City limits. In small towns with populations below 200,000, incinerators should, and are likely to be a prominent feature in Municipal arrangements; but, generally, they should be worked as subsidiary to a tramway project.

**Filling up
Insanitary
Tanks and
Cesspools.**

Tanks and cesspools constitute one of the most serious sanitary difficulties to be met with in many cities in India. The former are generally holes filled with surface drainage of inhabited sites, and the water is more

often than not used for domestic purposes, although absolutely unfit for such purposes. In many cities it will take years of persistent effort and the expenditure of large capital to fill up these tanks before the population can fully reap the benefit of sanitary works. In the meantime they should if possible be connected with drainage systems and drained to keep down the subsoil water level.

As regards the cesspool nuisance, the extreme injury which it inflicts on the health of the population and the vital necessity of abating that nuisance are points which should claim more attention than they do at present. The remedies which can alone avail are proper systems of sewerage with effective water supplies. Wherever such remedies have been applied, enabling the cesspools to be filled up, statistics tend to show that the death-rate has been reduced from 20 to 30 per cent.

In most cities there is a large floating population which cannot be trusted to clean their own privies, and in such situations public latrines are necessary, which can be connected with the nearest sewer, or in the absence of a sewerage system the latrines should be served by sweepers and the contents disposed of at the nearest pail depot or trenching ground.

**Latrine
Accommodation
and Public
Urinals.**

A proper establishment of urinals is absolutely necessary in every city, and without them it is unjust to enforce prosecution for committing nuisances which make some localities so offensive.

Every city and town should have a good system of sewers. In designing a system of sewerage it should be borne in mind that one which works well in European cities, owing to climatic and other conditions, works imperfectly or injuriously in India. The greatest difficulty in Oriental drainage lies in quarters where poor populations living in tiled huts have to be dealt with. It is impossible in these cases to prescribe either closets or expensive fittings by bye-laws which cannot be enforced. In such cases public latrines and urinals are necessary. The huts should have surface drains connected with a well-flushed collecting drain, connected with the nearest sewer, and in all areas liable to receive sullage and foul water impervious pavements should be insisted upon.

Drainage.

A good water supply is perhaps the most important sanitary agency in India. But if real benefit is to be obtained, the source of supply must be very carefully chosen and special precautions taken to protect it. It should be out of reach of the people, and the water should be conveyed to them in pipes to prevent any possible contamination. Such special precautions are very necessary in India where the people of all classes exhibit extraordinary and perverse ingenuity in defiling their source of drinking water, by bathing, washing foul and sometimes infected clothing, and vessels, cattle, etc., at such sources.

**Water
Supply.**

Before embarking on a water supply, chemical, biological, and microscopical tests are necessary, but it is necessary to bear in mind that reports based on the examination of a few samples cannot be accepted and no absolute opinion can be formed as to the true character without a large number of observations taken at different seasons of the year, accompanied by a careful examination of the site and the risks of contamination it is exposed to.

The regulation of buildings in most towns in India is utterly neglected and the sanitary state of large cities such as Bombay and Calcutta may be quoted as examples of the confusion which results from allowing people

**The
improvement
of
overcrowded
areas and**

**of buildings
with
defective
lighting
and
ventilation.**

to build as they please. The chief reason why the death rate is high in overcrowded localities appears to be that, as a general rule, they are occupied by the poorest classes unable to pay for sanitary arrangements and the difficulty of sewerage or access for cleaning purposes in such localities. Except on the upper floors, a large proportion of rooms are insanitary through various causes but chiefly through defective lighting or ventilation. The high death rate and prevalence of epidemic diseases have naturally turned a considerable amount of public attention to the necessity of building regulations and formation of Improvement Trusts, and it is hoped that the power to veto the occupation of all ill-lighted and ill-ventilated buildings and the opening out of crowded areas, will prove an efficient remedy for the existing insanitary state of affairs in nearly every Indian city.

**Benefits of
Sanitary
measures.**

Wherever proper sanitary regulations have been introduced, statistics show that the death rate has practically been reduced by from 20 to 30 per cent., and as the very important question of sanitation is now receiving increased attention from Government there is no doubt that the results of improved public health and the advancement of the standard of civilization will amply reward them for the efforts they are making in this direction

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NOTE ON DUST PREVENTION.

BY

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Although the question has more recently become merged in the wider and decidedly more difficult question of improved road construction to meet modern traffic conditions, the sanitary advantages of dust prevention measures in urban areas have been clearly recognized for some years.

In tropical climates street watering on metal or gravel roads is practically useless. Not only is the benefit transitory, but by assisting disintegration of the surface, the system leads to the production of dust in greater quantities.

As an alternative, experimental measures, both preventive and palliative, have been tried for some years in Colombo and they have materialized in improved methods giving appreciable benefit. Of the former class, but designed with the primary object of providing a more resisting road crust, granite sett paving for heavy traffic and asphalt macadam for light traffic, have proved most satisfactory and there is no question that in this direction lies the true solution of the dust problem. Although ultimate economy, combined with dust prevention and other advantages is assured, the high initial cost is a heavy deterrent to the use of these methods of construction, and in consequence recourse to cheaper preventive measures and to palliative measure is found necessary.

Stone cube paving laid on the Kleinpflaster principle was tried but not found satisfactory under heavy traffic. Concrete blocks with a broken rubble facing were used for bullock cart tracks, but are now being replaced by granite setts on concrete.

Tar macadam of various kinds was experimented with and is still used, but the Works Engineer reports that with the hard gneiss stone available, it is difficult to obtain a conglomerate neither too brittle nor too soft, and it would not appear that the extra cost over ordinary macadam is warranted.

It should be noted that with all non-dust-producing surfaces, efficient scavenging is essential, even more so than with ordinary macadam, as the dust brought on to the roads from outside sources is more easily raised by wind and traffic.

As palliatives or dust layers, Tar, Tarco, Tarvia, Liquid fuel waste, Liquid fuel and hygroscopic preparations have been tried. The latter class of preparation appears to be useless and Tarvia has no advantage over ordinary tar.

Tar and Tar Compounds applied cold to the swept surface give excellent results. They should perhaps be classed as preventives as they improve the surface, lessen the production of dust and prolong the life of the road.

Tarco gives better results corresponding with its higher cost.

As a dust layer liquid fuel, and more particularly the waste from liquid fuel tanks, gave unexpectedly successful results.

In dry weather one application remains effective for two to five weeks, dependent upon the situation of the road and the nature of the traffic. No additional watering is necessary and the dust is completely laid even under fast motor traffic. In wet weather the result is not so agreeable as may be seen from the note attached to the annexed statement supplied by the Works Engineer of the dust laying work executed in 1911.

Dust laying 1911.

—				Square Yards.	Gallons per Yard.	Cost per Yard.
						Rs.
Oil fuel	...	...	...	112,560	'137	'0243
Tar	...	...	...	58,877	'150	'0540
Tarco	...	...	...	18,433	'217	'1305
Tar and Oil	...	...	...	40,033	'183	'0432

NOTE.—The results of oil fuel in wet weather are :—

- (a) much mud,
- (b) greasy and slippery surfaces which "hold" the water abnormally,
- (c) consequent to (b), very serious disintegration of road as the traffic grinds through the surface and lets into the body of the road the mixture of oil and water.

ALL-INDIA SANITARY CONFERENCE MADRAS-1912.

THE PREVENTION OF DUST IN INDIAN CITY ROADS AND STREETS.

*By E. P. Richards, M. Inst., C.E., M., Inst., M. & C.E., M.I., Mun., E. M.R.,
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INTRODUCTION.

Had I leisure time, I would have found much pleasure in presenting a very full paper dealing minutely with most phases of the problem of dust prevention, both here and in Europe; but circumstances have compelled me to confine myself to a skeleton note, containing some information that may be of guidance to Municipal and District Board Engineers, Presidents of Municipalities, Medical Officers of Health and others who are attacking the dust problem in India. I am not likely to be present during any discussion, but I will gladly endeavour to reply by letter to any one seeking more technical information on the matter contained in this note.

The bibliography of road-work and dust prevention is now very considerable and a great number of books have been written during the past ten years, but almost all treat solely of European and English conditions. I therefore confine myself to a few notes on what are I believe the best and most economical methods for India.

Chief methods of Dust Prevention.

The prevention of dust in towns and cities can be obtained chiefly by good road-making, and by the suitable after treatment of good macadam road surfaces. There are other secondary and assisting means, but their effectiveness depends always on these two factors.

The present practical methods of eliminating dust in Indian cities and towns may be enumerated in their order of general use and importance as follows:—

- (1) Good road-making.
- (2) Suitable treatment of good road surfaces with special tars.
- (3) Tar-macadam and other road constructions in dense heavy traffic areas.
- (4) Effective, regular and non-destructive road-watering.
- (5) Regular sweeping and scavenging with proper plant.
- (6) Regulation of the underbody-construction of motor-cars.
- (7) Regulation of the speed of motor-cars.
- (8) Rules enforcing proper widths of wheel-tyres for bullock and merchandise carts.
- (9) Rules relating to the construction of tramway tracks and the watering and cleaning of tramway rails.
- (10) Provision of grass strips and shade-trees.

Creation and composition of Indian dust.

The dust of Indian roads and streets is very closely similar in origin and composition to the dust of European cities, largely, about 85 to 95 per cent. is found to be composed by bulk of pulverised road-metal and binding, and about 5 to 15 per cent. of finely triturated dung. This is a rough analysis, and does not mention about 1 to 2 per cent. of broken up vegetable matter that is usually present apart from dung. The most usual analysis found by bulk is about 90 per cent., 9 per cent. and 1 per cent. respectively. Members of the conference can verify these results in a rough but sufficiently truthful manner, by carefully collecting half a ton of average street dust, thoroughly mixing it, and then experimenting with half a cubic foot of

the mixture at one time. By mixing it up with water, and then allowing settlement, most of the powdered dung and vegetable matter will rise to the surface, and can be collected, dried, and measured cubically, and also weighed; comparison being made with the larger residue after drying the same. A second sample can be measured, weighed, and then spread $\frac{1}{8}$ of an inch thick on thin iron sheets over a hot coke fire, and the sheets and $\frac{1}{8}$ " layer of dust must be made red-hot, until the slight smell of burning dung is no longer perceptible. On re-collection, a difference of weight and bulk will be found to have taken place, representing the loss of much of the dung and vegetable matter. Really exact work is a complex process for the laboratory, and the taking of samples even for very rough analysis requires good personal judgment. Heavy and impalpable grains of stone-dust are sorted apart hourly by every breeze and passing motor, and the further from the road centre, the finer and lighter is the dust.

The important point of all road-dust analysis is the immense predomination of pulverized macadam.

Perhaps this last fact can be brought home in another way. A good macadam surface, 4" thick, will, if well cared for, wear down to a thickness of only $1\frac{1}{2}$ " before it goes into holes. Two and a half inches of solid stone and binding material have disappeared, actually gone, in the form of dust; or in the form of wet dust, which is better known to us as mud.

In a fairly decent road surface one may find a hole or hollow worn out, there is nothing loose in it, except perhaps a little dust or mud, but the materials that once occupied the cubic contents of this hole have been wetted and splashed out as mud, or have been blown out by the winds of heaven or by the offensive winds of motors and vehicles. The wearing away of only 1" of road metal on a 30-ft. macadam road-width, one mile long, represents about 900 solid tons of dust (or mud) and if the wear has taken three years, it means 300 tons of dust a year per mile: probably from $\frac{1}{2}$ a ton to $1\frac{1}{2}$ tons a day according to traffic variation. Much of this dust has to be removed, as dust, or as mud: but a very considerable amount is carried by the wind into houses, on to roofs and gardens, and as mud and silt in suspension a good deal finds its way into roadside ditches, sewers and drains. The impalpable atoms will discolour the air and may be carried hundreds of yards.

It is not my province to deal with the problems and effects of bacteria and germs in dust, but I may point out that the less dust there is on a road, the better chance has the fierce Indian sun of killing them. Under half an inch or more of road dust, there is considerable sun protection for germs. It is also not in my jurisdiction to discuss the evil effects of dust on human health. The main points for the engineer are that dust is inimical to human health, to human lungs and eyes; that dust is excessively unpleasant, and is a spoiler of the beauty of roads, streets, buildings, trees and flowers, and is a pollution of the pure air. The elimination of dust has therefore become one of the newer problems of road and city engineers. We have seen that dust is chiefly made by the attrition of road surfaces. It is this attrition which we have to prevent. We are all well aware how the introduction of petrol-driven vehicles has enormously aggravated the dust nuisance—but we must also bear in mind that nearly all cities are growing, and, in general, the ordinary traffic of to-day is much greater than it was twenty years ago in the same road; that is, there is more dust being made to-day than there was twenty years ago. The rubber-tyred motor vehicle does not do much in the primary attrition of road-metal, but its wheels help to rub coarse dust into fine dust, and the finer the dust the more mobility it possesses. The rubber tyre, especially in wet weather, and after road-watering, acts like a sucker and pulls out small and even large stones, but does not grind them up—the slow iron tyre grinds up the sucked out fragments. The chief cause of dust from a swiftly travelling motor-vehicle is the violent compression of air in front and the partial vacuum behind. The air is blown away in front and sideways, but mostly sucked powerfully back under the car to rush up behind and fill the travelling vacuum. While the air performs this dual action, it sweeps up and mingles with itself the dust. The effect is wonderfully well known to most of us and we have personally seen men at home hastily sticking their heads into roadside hedges to escape

suffocation, doubtless returning into the road with new light on that ancient writing "dust thou art and unto dust shalt thou return"—but this was some years ago, before engineers had so earnestly taken up the problem of dust prevention.

The remainder of this paper will consist of a separate note upon each of the ten means of dust prevention mentioned on page 1.

(1) *Good road making.*—Under this heading I wrote a boiled-down treatise specially for this paper, in which I tried to give all the chief information required in my opinion, by an Indian road engineer for making the most perfect and up-to-date macadam.

I found I had written some 5,000 words and even then I had, in my effort to be concise, been compelled to omit much useful matter and many "tips" vital to success. I have, therefore, abandoned the attempt. I wrote for my own staff at Madras a pamphlet that gives much of this information.

That paper is out of print, but, urged persistently by the Madras Government I have now a second edition nearly ready for the press, and this will contain those full and minute particulars and instructions that would be out of place, could not be illustrated, and would occupy far too much space in a general note for a conference.*

Too much stress cannot be laid on the importance of good macadam road-work in preventing dust. Indian city roads are almost solely macadam roads. Good roads wear slowly and produce dust and mud slowly. Good roads can readily be treated with dust preventives; but nothing of this kind can be done with a bad macadam surface, and it produces dust and mud at a surprising rate. The point I wish to impress on members is, that good macadam work is of the most primary importance in setting out to make dustless a net-work of city roads.

I may mention that the chief faults I have observed in Indian road making are—

(1) Neglect of the extreme importance of equality in size of road metal. Ignorance of the fatal result of using metal containing groups or even a small percentage, of stones of a size high above the average size.

(2) Complete breaking up of the old worn surface prior to re-coating, instead of using it as a foundation, scientifically patched, cross scored, and prepared for the new coat.

(3) Ignorance of the importance of smoothly spreading the stone layers, and ignorance of the methods to be observed during the whole process, to obtain success.

(4) Indiscriminate rolling, instead of definite ordered successions of dry and wet rollings to produce definite effects at each stage of the road making, also rolling at too rapid a speed.

(5) Use of improper binding materials, and utterly improper application of good binding materials.

(6) Indiscriminate watering; and watering with chatties, pots and hoses, instead of with proper carts during road-making.

(7) Entire lack of intelligent ordered co-operation between roller drivers, road overseers, maistries, contractors and coolies.

The duties and responsibilities of each party are not defined.

With organization, care, patience, personal tuition, frequent personal inspection and demonstration, *plus* a judicious mixture of persuasion, coaxing, cursing, and fining—the Indian road-staff can be made to turn out quite decent work, sometimes even comparable with first-class English road-work. And always, one's efforts produce something much better, more lasting, and more pleasant, for both foot and wheel, than is the average Indian macadam. And with encouragement and judicious praise, when deserved, the roller drivers and overseers can be made to take a genuine interest and pride in their work. There is very much more in good road making than the layman would think, and good work cannot be obtained except by taking constant pains; but when once thoroughly taught, a staff gives very much less trouble than at first.

* *Note.*—This little book will, I understand, be supplied gratis by the Madras Government to any Presidents of Municipalities, District and Municipal Engineers, Medical Officers of Health and others who may require it, in the Madras Presidency. It will contain chapters on tar-spraying and dust prevention. The title will be "Indian Macadam and Laterite Roads, and Dust-Prevention."

(2) *Suitable treatment of good road surfaces with special tars.*—The Engineers of nearly all European and English towns and of nearly every County Council in Great Britain have arrived at the fact that either “tar-spraying, or tar-painting” is the best method of making roads comparatively dustless. This statement requires a qualification, viz., it applies strictly to roads on which ordinary macadam is and can still be used fairly economically as a road surface. In other words, tar-spraying and tar-painting are not suitable for roads under genuinely dense and heavy traffic. Where traffic is very great and heavy we must use pure asphalt on concrete, wood on concrete, granite setts on concrete, or a similar special road construction. But where traffic is only of moderate weight, though of considerable density, such as that in Central Mount Road, Madras, and in the central parts of most Indian cities, there tar-spraying is successful, and enables macadam to withstand the wear and tear of dense traffic, especially if the spraying be renewed at suitable intervals.

At home there are numerous towns in which nearly every road and street is found to be tar-sprayed and very pleasant and dustless are those towns. In most English counties nearly every main road has for some years been tar-sprayed or painted for mile after mile through the open country, and the average English county council re-sprays from 50 to 200 miles of roads every year. These roads are excellent and very dustless.

About 95 *per cent.* of the total length of tar-treated roads in Europe are found to be tar-sprayed or tar-painted—only about 5 *per cent.* of tar-treated roads are of tar-macadams—chiefly because of the much greater cost of tar-macadams, and because this construction is not necessary except where traffic is heavy as well as dense; and there are other secondary reasons, I will mention, under the head of tar-macadam.

The dust-reducing effect of oiling only lasts from one to four months, but the smell will last a year. Where oil is abundant and cheap, as in parts of Canada, oiling is used instead of watering.

The oiling of roads, we found out years ago in Europe, was futile and costly; and even destructive by reducing cohesion; numerous chemical binders have also been put on the market every year, but tar still easily holds the front place.

The main point for this conference is that tar has been found the best and most economical and most practical dust preventer on macadam roads throughout the world. The next point is that tar-spraying is nearly always superior to and more economical than tar-painting; and 90 *per cent.* of the above 95 *per cent.* of European tar-treated roads are of tar-sprayed macadam.

The next point is that tar-spraying can be done very successfully in India if the right plant, the proper tar, and correct methods are used. Another important fact for this conference is that road tarring increases the life of a macadam road by from 50 *per cent.* to 150 *per cent.* or more. Here I must point out that tarring one short bit of road may not make that bit much better as regards freedom from dust, because one short experimental length is only one small non-dust creating area in a whole network of dust-producing macadam, and quickly it will be covered with dust blown on to it from adjoining non-treated macadam, especially if the direction of the tarred road happens to coincide with a prevailing wind. But, all the same, every piece of tar-sprayed road done, lessens the total area of dust-producing macadam, and has its effect. A very large area of road can annually be tar-sprayed at small cost, and quickly; but an equal area of tar-macadam is quite prohibitive in cost. The order of tarring should be first the fast traffic routes, then the adjoining roads, then wherever you can afford it.

At one time there was some alarm felt, especially in France, on the ground that road-tarring might deleteriously affect vegetation and trees—happily this has not been found to occur, and I have, myself, seen miles and miles of roads that annually had been tarred, fringed on both sides with an unbroken display of delicate wild flowers and grasses which often drooped on to the actual tarred surface itself. The only evil result of road-tarring appears to have been the poisoning of fresh-water fish in several rare localities, where quantities of the first rain-washings off newly-tarred roads had flowed into small trout streams. Even this difficulty has now been eliminated in a simple manner by making the washings flow through a small sand and gravel filter bund placed in the outlets of the ditches.

There is another good point to be mentioned about the tar-spraying of roads. Noise is decreased in a wonderful way and if an extra dose is given to roads in the vicinity of clubs, hotels and hospitals—the benefit obtained is very marked. Noise means friction, abrasion, wear and tear; dust. Silence means their lack. Good tar-spraying makes a road silent and dustless, *because it has stopped the macadam surface wearing away*. It does this in four ways, viz., by increasing cohesion of the road metal and binding, by providing cushion-joints between all particles and stones, by providing a certain amount of cushion-layer over the surface of the macadam; and by making the road smoother.

I could write for days about different kinds of tarring, the different machines and methods of application, about variations of tars, the effects of various temperatures on tar, the composition and distillation of tars, on bad tars and good tars, etc., and I tried to write out a very brief practical description of what to do in India to secure a good dustless tar-sprayed macadam, but I found I had covered far too much paper, and yet had not said all that should be said for the guidance of the Indian road engineer who has not had the benefit of actual experience and the very technical information required is dealt with in the little book I have already mentioned. It may, however, be in place and be of general interest to give a slight description of the machines best suited for India:—

(1) Tar-spraying and painting machines may be classified as follows:—

- (a) Spraying machines, that force hot or cold tar into and over the road surface.
- (b) Tarring machines that paint, pour, or brush tar *over* the road surface.

Machines of class (a) are the best for India. Machines of class (b) can only be used successfully on very porous roads, such as on some of the porous flint roads in Southern England and Northern France.

In tar painting the tar is simply spread evenly and allowed to soak in. Members will comprehend readily that an impervious road, such as a granite road bound with laterite or kunkur, will only soak up the tar in a slight degree, and that no real penetration will take place.

Machines for India (large).—I am confident from observation here and in Europe that the high-pressure tar-sprayer is the best machine for India. There are many varieties and they have been brought to great perfection during the last six or seven years, and all are good in their own way and for their own work. A machine of the very best for general tarring in India on a large scale, is one holding from 500 to 1,000 gallons of tar at a filling. Such machines are composed mainly of a four-wheeled underbody supporting a tank to contain the tar; plus a powerful pump actuated by chain-gear from the back road-wheels, with the spraying pipes and nozzles fixed low down at the back. The actual spraying device consists of a horizontal pipe, generally seven feet long, fitted with brass sprayers at intervals of 9 inches. The sprayers in principle, are very like a gas-jet burner, but are turned upside down, and direct a flat flame-shaped continuous and very powerful jet of tar on to the road surface. The sprayers are usually about 8 inches or so above the road-surface. The machine should be fitted with a crane for raising tar barrels to fill the tank. Inside the tank is a tar heating coil of steel piping.

The whole machine is drawn by a steam roller. When tarring is to be done the tank is filled and the roller is coupled up to the front of the machine. A flexible steam pipe is coupled up from the roller boiler to the tank heating coil, and live steam is turned into the coil. The tar should be heated to a temperature of not less than 50 degrees hotter than the road surface in the Indian sun. The pressure and the quantity per square yard have both to be carefully regulated and fixed before starting the work. I have found that 75 lb. on the square inch pressure, and about one gallon of tar to every $3\frac{1}{2}$ square yards of road surface, give the best results for the first tarring done on the average Indian road. After twelve months, a second coat should be given, but this need only be at the rate of one gallon to 8 square yards. Keen observation and common sense must of course be used to guide each engineer in minor variations for his own special district or city.

The cost of a 500 gallon first-class machine, with spares, tools, etc., complete, delivered at an Indian port, is about Rs. 4,500, and for a 1,000 gallon machine, about Rs. 5,250. These big machines can easily tar a mile of 30 feet wide macadam in a day, and they do their work most admirably and economically. Speed of tarring is a great consideration in busy roads: in addition, an even temperature is easily maintained in the large body of tar. Screens are fitted round the spraying nozzles to prevent dissemination of the atomized tar.

Small Machines for India, to be drawn by hand or bullock.—There are many to choose from; but I advise that the best hand machine for this country is one with a capacity of not less than 150 gallons, and preferably 250 gallons. They are usually fitted with the following essential parts—Undercarriage and four road wheels; a good firebox well lined with fire-bricks; a tar strainer in the filling cover; a powerful brass lined double acting hand-pump to obtain even spraying pressure, a large air vessel on the pump delivery to obtain even spray-pressure; a second tar strainer between pump and delivery nozzle, and a sythe-shaped hand pressure sprayer. The latter is composed of a metal tar-tube, connected to the machine by a flexible armoured delivery tube about 25 feet long. At the termination of the metal tube is a rotary jet, which directs a strong downward spray on to the road metal. The metal tube is provided with handles, which are held by the man operating the jet.

A good hand-pressure machine of a 150 gallons capacity, delivered complete, with spares, at an Indian Port, will cost about Rs. 750, and one of 250 gallons, which is preferable, would cost about Rs. 1,300.

There are many good makers, and some of their machines are described in the small book I have mentioned.

In tar-spraying work, the following points need the most careful attention:—

The tar used must be according to a proper specification, and must be first-class material distilled specially for road-work and only from tar obtained in the manufacture of coal-gas for illumination and heating. Tars from suction-gas plants, blast furnaces, kerosine-gas plants and from other sources are not successful, and are seldom or never used in Europe, although they are cheap. The specific gravity, the percentage of free carbon, the viscosity at 60°, and the temperature of distillation, are all of great importance in tars distilled for road-work; and especially for Indian road-work. The correct preparation of the road-surface to be tar-sprayed is absolutely vital to success. The macadam should be in good condition, or be put into good condition by really skilled flat invisible patching and steam-rolling. It is very wasteful and very bad practice to perpetuate a bad macadam surface by tar-spraying it—for even if bad, its wear will be much stopped and its life as a bumpy road will be prolonged. A good smooth macadam surface requires a fairly heavy initial cost of tar, but its next spraying, usually after twelve months, need only be a light one—and the good surface is preserved from year to year. But if, after two years, the original bad surface has to be remade, then the value and effect of all previous tarring is lost.

Tar-spraying can only be done successfully when a road is perfectly dry for at least one inch into its surface: and all dust and mud must be scrupulously and vigorously removed by hard sweeping with pucca bass brooms used in the correct manner.

As soon as the surface has been sprayed, gritting should be done. The composition, perfect dryness, and the size of the grit used, are all of great importance to success. The object of gritting is threefold; first to absorb the surplus tar not driven into the macadam and thus allow rapid resumption of traffic, secondly, to replace the superficial binding that was removed purposely by previous hard brushing; thirdly, to form a tenacious, durable and tightly adhering resilient carpet on and in the macadam surface: that is, not so much *over* the road metal, as over the *matrix* containing the separate stones of the road-surface.

The whole process of brushing, tar-spraying and gritting a moderate length of good road in dry weather can be done in 12 hours at home, but in India from two to three days is generally occupied between the cessation and resumption of traffic—on account of the higher temperature, the shorter hours of labour, and the imperfect grit that generally has to be used. The most perfect grit is of granite, from $\frac{1}{16}$ " to $\frac{3}{8}$ " in size, mingled thoroughly together.

The mechanics and cleaners working tar-spraying machines must always be provided with large close-fitting plain-glass goggles to protect the eyes from atomized tar, which resembles a black smoke. They must also be provided with a full allowance of cocoanut-oil, turps, kerosine, and monkey soap, in order to clean their hands and faces and often their legs and thighs from tar, which is a sharp irritant when applied in the hot atomized state. In addition, each man must be provided with thick boots, leather leggings and two pairs of thick overalls, for use and protection when tarring. The public should be kept away from the spraying apparatus when at work, or their clothes will be quickly and irretrievably spoilt.

(3) *Tar-macadams and other road constructions for dense heavy traffic areas.*—Roads are found in most great cities, where the ordinary macadam would have to be renewed from every twelve months to two years on account of very heavy and dense traffic. Tar-spraying or painting is not suitable for such roads; and in India, where pure asphalt on concrete, or wood-paving on concrete are too prohibitive in cost, or where granite sets would be too noisy and unsuitable; then *tar-macadam* is likely to come in as the best substitute. Tar-macadam, well done, well-cared for, and well-scavenged, is dustless smooth and very durable—it is of course far costlier than tar-spraying, but is very much cheaper in initial cost than pure asphalt, wood, or granite set roadways.

There are three well-known methods of making tar-macadam roads:—

(i) Perhaps the oldest is that called the “Sub-binder system”, of which several variations have been patented. A paste is made of fine granite grit and of distilled tar, of tar and pitch, or of a similar bituminous binding liquid; and, after smoothing and preparing the old road-surface, about $\frac{3}{4}$ of an inch to $1\frac{1}{2}$ inches of the paste is spread thereon. Upon this paste is then spread ordinary road-metal to a loose thickness usually of from 4 to 6 inches, care being taken that the road-metal is clean and absolutely dry. The loose layer superimposed on the sub-binder is then steam-rolled until the macadam is pressed firmly together, and the sub-binder having nowhere else to escape is squeezed and worked up evenly into the stones until it begins to appear freely at the rolled surface. A thin coat of distilled tar is then painted or spread over the work and is at once thickly coated with granite chippings. Steam-rolling then proceeds until a perfect surface is obtained. The sub-binder system makes good work, but takes a great deal of labour and tar material; it has largely been replaced by the—

(ii) Tarred stone system, in which clean road-metal is dried, heated and well coated with tar. This is effected either at the quarries or at the work site, by means of special power-driven “tar-macadam mixers.” Many large quarry owners in Europe now send out by rail quantities of tarred stone ready for use. Before laying down the tarred stone on a road, the old metal is removed and the foundation surface carefully rolled hard and solid; or else the existing road surface is carefully cleaned, brushed, patched and rolled. The tarried macadam is then put down and treated very much as though it were ordinary road-metal, except that little or no binding is found necessary. When a firm smooth surface has been obtained, it is finished off by thinly tar painting and abundantly gritting as before, followed by steam-rolling.

(iii) A later system, which is cheap and is finding considerable favour, is that of tarring the road-metal after it has been spread and slightly steam-rolled. Hot sunny weather is very desirable to ensure success. The old worn-out road surface is smoothed and cross-grooved exactly as for ordinary modern macadam recoating work. The broken stone is spread usually 4 inches to 5 inches thick as a loose layer, and is allowed to remain unrolled for a day during exposure to air and sun. Next day when all dew has dried off and preferably, after the sun has warmed the stone layer, the latter is rolled dry sufficiently to support the wheels of a large spraying machine. The dry stone layer is then tar-sprayed very much in the ordinary way, but generally with cold and more viscid tar and at a lower pressure, and in will be found that most of the stones and especially the upper stones, have been fairly well tarred all over. Steam rolling then proceeds until the layer is compressed, hard, black, and smooth. A second tarring, lighter, and at 200° to 250° temperature, is then given and the whole is heavily gritted and rerolled until the finished appearance is obtained. This system is economical of both tar and labour, and produces very good work if done with reasonable care and intelligence. At home, the

difficulty lies in drying the stone, especially if the weather be cold. English sunshine is too uncertain, and, except during a few months is too weak to dry and warm up the stone layer sufficiently for success; hence the very general use at home of machines for drying and at the same time tar-coating the road-metal. In India, however, we have perfect climatic conditions for this method of tarring the metal *in situ*.

(4) *Effective, regular, and non-destructive road-watering.*—The best ordinary macadam in the world is soon injured and ruined by watering it with roseless hose-pipe jets, and, in a lesser degree, when chatties, pots or goat skins are used. Ordinary good macadam damaged by bad watering is very unpleasant for driving and walking, especially for those with bare feet; it is also very destructive to motor and cycle tyres. The binding is washed out and forms a deposit on the road-sides, where it dries, and the wheels of bullock carts and the shuffling feet of bullocks send it up in thick dust, and after rain the same deposit forms an unpleasing mud. The road surface is found to be a mass of stud-like points, large numbers of them exhibiting recent fracture from the passage of an iron tyre. The chipped-off stone and stone-dust forms a sharp gritty and destructive deposit—it is, as it were, emery to the grinding wheels. Actual individual stones are also loosened and blown out, leaving weak spots that quickly develop into holes—and holes, as I have shewn, are cavities formed by converting stone into dust. Where the bullock cart can go, there can go also the pucca water-cart. It should be built on English lines, and be on four wheels with a light pole, and not the massive structures I have seen that put as much as 35 lb. steady weight on each bullock's neck.

Where traffic is too dense and roads are too congested to permit of ordinary water-carts, a first class heavily tarred macadam, or, better, pure asphalt or concrete, wood on concrete, or setts on concrete should be put down, and the street be washed with hoses, especially in the very early morning. It is very questionable indeed, if even good tarred macadam can stand the ordinary hose, and such severe watering will certainly necessitate more frequent re-tarring and gritting of the tar-macadam surface. It is also believed by many that the hose is a much greater nuisance and hindrance to traffic than is a well-driven water-cart. In roads where bullock carts are tolerated, water-carts are a far lesser evil—one knows where the water-cart is going, but the hose may turn in any direction at any moment, without warning. A pair of lightly built fast-walking bullocks are best for water-carts, and the drivers should all be picked men. The work is, in my opinion, done quicker and more evenly with a good water-cart staff than with the average hose staff: but the most serious objection to the hose, is the destructive effect on all kinds of macadam.

Morning watering should as a rule be commenced about 8 A.M. in India, and afternoon watering not earlier than 4 P.M., otherwise the water is evaporated before the two chief traffic maximums occur. Where it can be afforded, midday watering is a great godsend. Economy can be effected by omitting this latter on still days; but watering gangs should have instructions to go out on their own initiative and begin work and do extra work, when a high and hot wind occurs. Watering with proper carts is the only method allowable when laying down new macadam, and on ordinary untreated macadam.

(5) *Regular sweeping and scavenging with proper plant.*—Do not let any one run away with the idea that tarred road surfaces or even asphalt and wood surfaces will do away with or very much lessen road watering. The smoother the surface, the less difficulty has the wind in picking up what dust there may be upon it, and while we employ animals in our cities there will always be dust. Their droppings and the slow pulverizing of tarred-sprayed and tar-macadam, asphalt wood and granite will continue to create some dust. Tarred surfaces stand brushing very well, and in important streets full of fairly dense traffic the whole surface should be watered and brushed every night or very early in the morning. The wetting is to clot the dust. During day time orderly chokras provided with the usual hand brushes and tin receivers to pick up droppings and paper, etc., should be employed. Motor unions should notify members to drive considerably and intelligently when passing working orderly boys. Roads under light traffic can be brushed once or twice a week in regular rotation, always immediately after watering. Thousands of two-wheeled horse-drawn sweeping machines are made and used every year in England, and save much

labour in dealing with the lighter-traffic ordinary macadam roads, where washing with hose pipes cannot be done without destructive effect. For India these machines must be mounted on two side wheels and a front castor-wheel, because the bullock walks with a much more undulating action than the horse—and this prevents the brush of the two-wheeled vehicle operating smoothly. The only effective hand road-brush is the "bass broom". The handles should be short, otherwise a coolie will not use the broom in a vertical position. Large numbers of these brooms are now made in India. It is very important to remove all swept-up dust as soon as possible, and not leave it on the road side, otherwise it is soon redisseminated by the wind, and by foot-traffic. As tarring operations proceed, roadside after roadside should be thoroughly cleaned of dust, and once well done, there will in future be a comparatively small amount of this work. If it is not done, the same dust will have to be removed again and again from the road to the roadside. Road sweeping machines, at work, should follow on fairly soon after road-watering has been done; the dust and droppings will then be in a damp clotted state, easily swept together, and without nuisance.

(6) *Regulations are needed as to the underbodies of motor cars.*—One often sees two cars of the same size, going at the same speed, but producing very different dust effects. The smoother the underbody the smoother and less dust-disturbing are the eddies produced. Cars with underbodies high above the road are noticeably less dust-disturbing—but unfortunately the low car seems to be increasing in popularity.

(7) *Regulation of the speed of motor cars* in roads full of wheeled and foot traffic is still badly wanted in this country. Motor unions could do a great deal by pointing out to their members what bad form it is to drive at excessive speed in crowded roads. Even on asphalt, the dust from droppings is whirled well up by a motor travelling at unnecessarily high speed, and produces most unpleasant results to every human being in the road. Suppose a man has 3 miles to go, and travels at 16 miles an hour (a dust raising speed), it takes him $11\frac{1}{4}$ minutes. If he travels at 10 miles an hour it takes him 18 minutes, with 40 per cent. less wear and tear on the tyres. What value is $6\frac{3}{4}$ minutes saved in India?

(8) *Width of tyres.*—Rules are now being enforced or considered as to the width of iron tyres on springles's bullock and hand-drawn merchandise carts. The common existing tyre is only $1\frac{1}{4}$ to 2 inches in width, and the load on each wheel is generally half a ton, and often one ton. Such tyres are highly destructive to every kind of road surface and that destruction produces an enormous amount of dust. There is a secondary action that makes the narrow tyre particularly destructive in India. The bullock pole is a rigid fixture, and the swaying action of walking bullocks makes each tyre move from side to side while it is pressing on and advancing over the road. In a lesser degree, the same effect can be observed in hand-drawn carts, thus producing a true grinding action in addition to the crushing force of the big direct weight concentrated on a very very small area of road metal at any one moment. Perhaps the easiest and fairest way of obtaining better tyres is to put an extra tax of a few rupees per annum on these narrow-tyred vehicles with exemption for all carts having tyres of a proper width: with a proviso that within two years of the coming into effect of the rule, no narrow-tyred vehicles will be allowed on the road. I have found that considerable number of the rough heavy hand carts drawn by four or five men are owned by one of these men who may only be making from 15 to 30 rupees a month.

(9) *Tramways.*—I think there are no tramway systems in India owned and run by municipalities. The present day Tramway Companies mostly got their concessions many years ago, and those concessions generally lack adequate provision as to the construction and upkeep of the tracks. In the whole of Europe I believe it would be very hard to find a case of tramway rails in juxtaposition with macadam. All are paved with stone setts on wood or asphalt, and this work is generally so well done that the track is abundantly used by ordinary vehicles and can be crossed anywhere without danger of ripping off a wheel or the certainty of severe jerking and bumping. In other words the tramway track has not cut a big strip out of the usable roadway. In most dense traffic roadways in Europe the tramway pavements are of wood or asphalt, and in suburban areas of smooth setts well laid on a continuous concrete underbed extending not less than 2 feet outside the rails, viz., for a standard $4' 8\frac{1}{2}"$

single track, the concrete bed and setted strip is not less than 9 feet wide. No even setted surface can be preserved unless the setts rest on not less than 6" of cement concrete. Continuous concrete is not used even under the rails in some Indian Tramways and concrete under setts either very rarely or never.

Under the usual concession, the Tramway Company has to maintain the roadway between the rails and for one foot outside of each rails while the Municipality maintains the rest of the roadway. The results of this dual control are very unsatisfactory. The rail level does not alter, but the macadam level begins to alter from the day it is put down between and against the rails. In a month or two, or less, the macadam will be lower than the rails, if it has been laid level with them. To prevent this rapid relative lowering, the Tramway Company generally fills the space between rails well up, and where a stream of traffic crosses a double track one gets the most atrocious bumping, and but a few months later the same track is exhibiting deep holes between the rails. I know a length of excellent tar-sprayed road containing a single tram-track and a passing place. I have seen this tar-sprayed roadwork presenting an excellent smooth dry and clean surface, except where it was being splashed by mud and water from the hollowed out ordinary macadam between the rails!

The practical remedy is for the Municipality and Tramway Company to negotiate in a friendly manner and arrange that all the roadway be made and maintained by the Municipality; the parties to determine what has been or should have been spent per annum in tramway track road upkeep, and the Tramway Companies should then pay that sum annually to the Municipality.

In granting new tramway concessions the Indian Government should be guided by the advice of a city engineer with practical European tramway experience, otherwise the interests of the public will not be sufficiently guarded.

Tramway rails should be wetted before the flange-grooves are cleaned; but there is a favourite and permitted method of doing this in another way in India. A small but very dense cloud of dust is seen rising and spreading out steadily without cessation behind a moving tram-car—a coolie is perched behind the travelling car and holds a brush pressed down in the rail-groove. The groove is full of dust, which is being violently swept out, and is rushing up into the partial vacuum behind the car. By means of a water-box on the car and a bit of pipe, this offensive and well-known dust nuisance can readily be stopped if the Tramway Company think it worth while.

(10) *Shade trees* planted along roads are helpful to some extent in preventing dust, especially in India. They keep road-surfaces from drying too quickly after watering, and they reduce wind-strength; and it will be found by observation that the average tree-shaded road is less dusty than the average open road under the same conditions of traffic.

Grass-strips down the centres of very broad roads, and along the margins of narrower roads, are of quite appreciable use in reducing dust. After high wind in the ordinary grassless road, accumulations of dust will be found mostly at one of the road sides. Unless removed it will remain there until foot-traffic, variable gusts, or distinct changes of wind, remove it on to the road on to the other side, or until it is propelled along the road. Dust is generally moving diagonally towards either one or the other side of the road; and if a grass strip be there, most of the dust is caught in the grass, and is permanently retained. Each time rain falls and each time the grass is watered, all the caught-dust is washed down into the thick mat of grass blades—that is the chief reason why roadside grass looks so particularly fresh after rain or watering. The caught-dust has been washed down into it, and is out of sight. Wherever it can be done, roadside marginal grass strips should be laid down. The difficulty, of course, is usually lack of water. Perhaps the most effective place for a strip is between the macadam and the footpath.

EXPERIMENTAL SAND AND MECHANICAL FILTERS.

KING INSTITUTE, GUINDY.

Analyses are made quarterly by the Director of the King Institute, of the water supplied by the water works in the Madras Presidency.

Owing to the unexplained variation in quality of the filtered water from sand filters, Major Clemesha, who was then acting as Sanitary Commissioner for Madras, reported that the type of sand filter in use was unsuitable.

He said that the depth of broken stone underlying the sand layers in the filters was too great and tended to the multiplication of bacteria in the post filtration passages.

The type of sand filter constructed by us is similar to that adopted in European practice. Our sand filters have a depth of 2 feet broken stone with drainage tiles, 3 feet of sand and above the sand a constant head of 3 feet of water. The side walls of the filter are raised above the maximum water level to a height of $1\frac{1}{2}$ feet.

The total depth of a Madras filter is therefore $9\frac{1}{2}$ feet.

Major Clemesha proposed that the filter should be constructed of the following depths :—

One foot drainage layer.

Two feet 6 inches sand.

Two feet of water.

Six inches height of filter wall above water-level. This means a total depth of 6 feet and a saving in the cost of a sand filter. It will be observed that the total depth of sand which can be removed by periodical scrapings in the case of the Madras filter is 1 foot and in Major Clemesha's proposal 6 inches, assuming in both cases that the minimum depth of sand in a sand filter should be 2 feet.

As it seemed impossible to prove which type of filter would give the best results in the high average temperature of Madras, I suggested to Government that two experimental sand filters should be built at the King Institute and that from the results of analyses it would be possible to determine which was the most suitable type. It is also proposed to continue the experiment with different depths of drainage layers, sand, graded and ungraded and water, and to observe the increase or the decrease in number of bacteria which may follow. It will be noticed that arrangements have been made for the taking of samples of water at different depths in the sand filter, and inspection windows have been provided so that observations of the working of the interior of the sand filter may be carried out. The water entering and leaving the filter will be measured by meters.

The works were only started in March and delay occurred in obtaining the pumping plant, which is required to pump water from the river Adyar adjoining the site, so that the installation cannot be shown to the delegates under working conditions, but it is hoped that some interesting results can be brought forward at next Sanitary Conference.

Mechanical filters.—The Government of Madras having ordered tests to be made of the suitability and action of mechanical filters, it was proposed and approved that these tests should be carried out at the same time and place as the experiments with the sand filter. At present the mechanical filters that will be tested will be the Jewell and Paterson gravity filters and the Mather and Platt pressure filter, but it is expected that other types and systems of working may ultimately find a place in the experimental station.

Sunning tanks.—At the request of Dr. Maitland Gibson, Director of the King Institute, arrangements are being made for the construction and testing of sunning and sedimentation tanks so that these operations may be scientifically tested on a reasonably large scale. It is proposed to have two tanks—one lined with white-glazed tiles and the other with cement plaster so that the action of the sun by reflection from these materials may be studied.

MADRAS,
7th November 1912.

W. HUTTON,
*Superintending Engineer,
Sanitary Engineer to Government.*

**ALL-INDIA SANITARY CONFERENCE—MADRAS—
NOVEMBER 1912.**

MADRAS CITY WATER-SUPPLY.

BY

*J. W. Madeley, Esq., M.A., M. Inst.C.E., M. Am. Soc. C.E., etc., Special
Engineer, Corporation of Madras.*

1. *Sources of Supply.*—The Madras water-supply is part of a project undertaken with the object of utilising, to the fullest economical extent, the waters of the Corteliar river and its tributaries. This is effected by means of a masonry weir built across the Corteliar river at a place called Tamarapakkam (See Plate No. 1). This weir diverts the river—excluding the greater flood discharges—into a channel which feeds the Cholavaram and Red Hills Storage Tanks. From the lower of these—the Red Hills Tank—is drawn the Madras water-supply. The water from both tanks is also used to irrigate a first crop area of 7,500 acres, and a second crop area of 3,200 acres. The water thus used for irrigation is estimated to amount to about 3 times the present water-supply to Madras.

The Red Hills Tank is fed partly by rain falling on its own catchment area, but mainly from Cholavaram Tank which, in its turn, is supplied by the Corteliar river itself, by means of the channel starting at Tamarapakkam anicut, and also by the rivers Katankal and Bosikal (tributaries of the Corteliar) which are intercepted by the same channel that carries the waters of the Corteliar to Cholavaram Tank. The origin of the Corteliar river is the overflow from the Kaveripakkam Tank, but the water flowing down the Corteliar is diverted into the Cooum river by the Kasavaram anicut about 25 miles below Kaveripakkam Tank, and the catchment area above this point must be deducted from the total catchment area of the Corteliar in calculating the water available.

2. *Catchment area.*—The catchment areas of the system are shown clearly on Plate No. 1, they are as follows :—

	Square miles.	
River Corteliar, Tirutani and Nagari above Tamarapakkam anicut (coloured yellow and violet)	...	1,105
Red Hills Tank (coloured pink)	...	23
Cholavaram Tank ditto	...	11
Katankal river (coloured green)	...	62
Bosikal river ditto	...	44
Total	...	1,245
Deduct—catchment area of river Corteliar above Kasavaram anicut (coloured violet)	...	268
Net catchment	...	977

The storage capacity of the two tanks is as follows :—

	Cub. feet.
Red Hills Tank at its present F. T. L., (44'36 G. T. S.) is	2,162,000,000
Cholavaram Tank at its present F. T. L., (59'73 G. T. S.) is	579,000,000
Total	2,741,000,000

The average rainfall over the whole catchment area may be taken as 37 inches per annum.

The works so far mentioned—the anicut, channels, and tanks—are required for both irrigation and water-supply. The Madras Corporation made no contribution towards the cost of their construction which was borne wholly by Government. Their upkeep and maintenance are in the hands of the Government Public Works Department. For water taken from Red Hills Lake

for the supply of Madras City, the Corporation pay Rupee 1 per 1,000 cubic yards or a little less than one-tenth of an anna per 1,000 gallons. The total amount thus paid is about Rs. 22,000 per annum. To prevent contamination of the Red Hills Lake by cattle-washing, fishing, bathing, etc., the Corporation maintains a conservator and staff of men who are provided with a sailing boat to enable them to patrol the lake.

3. *Madras water supply channel.*—The works required to convey the water from Red Hills Lake to Madras were constructed solely by the Corporation, who also maintain them. The existing works comprise a valve house situated at the south-east corner of the Red Hills Tank and an earth supply channel which conveys water to Madras City.

The valve house contains the machinery for controlling the four valves, one on each of the four lines of pipes that lead from the lake, through the valve house, and continue on to the supply channel.

The supply channel has earth sides and bottom. It is $6\frac{1}{2}$ miles long with a gradient of 3 inches per mile. Most of this channel is carried upon an embankment, only a small portion being in cutting. At the Madras end the channel delivers its water into a masonry shaft 22 feet in diameter, from which lead the cast-iron mains of the city distribution system.

Faults of the existing water supply.

4. The chief faults of the existing water supply are :—

- (1) The lake is tapped at so high a level, that for considerable periods occurring on the average every other year, the surface of the water in the lake is lowered below the take-off and pumping becomes necessary to raise the water by pumping into the channel, [though there is still plenty of water in the lake below the take-off level.
- (2) Serious loss of water in transit. By evaporation from its $6\frac{1}{2}$ miles of water surface, and by percolation through its 13 miles of bank, the channel loses a large proportion of the water that enters it from the Red Hills Tank.
- (3) The channel will not carry enough water to supply the increasing requirements of Madras.
- (4) The channel is liable to contamination by persons bathing in it, or throwing things into it, by cattle that find their way to it in spite of the Corporation patrol, and lastly by the coolies who are in it every day cutting the quick-growing weeds which thrive in the slowly-moving water.
- (5) There is the constant danger of the breach of the channel sides. Minor slips frequently occur, and a complete failure of the channel such as would deprive Madras of its only water supply is felt by the Corporation Engineers to be very real danger against which they are constantly on guard.
- (6) There are no filters.
- (7) The distribution system is defective in that it is incapable of supplying water to consumers either sufficient in quantity or adequate in pressure.

5. *Effect of pumping on the health of the City.*—(Plate 2). It is interesting to give the results of an investigation into the effects of pumping at Red Hills Lake on the health of the city. The late Health Officer advised that the cholera returns should be taken as the best index available.

Adopting this advice, the death-rate from cholera from January 1891 to November 1910 has been plotted on the diagram in Plate No. 2, and on the same diagram are shown the levels of water in Red Hills Lake and the days on which there was pumping.

An examination of the curve shows that almost invariably an epidemic of cholera synchronises with pumping at the Red Hills, and that, the longer the pumping period, the worse the cholera epidemic. The only case in which there was serious cholera without pumping was in 1906. In that year it may be safely

assumed that the disease germs survived from the previous year which had witnessed the most deadly cholera outbreak of recent times, following the longest recorded period of pumping. In every year without exception when pumping has been necessary there has followed a more or less violent epidemic of cholera.

There is thus an undeniable connection between pumping and cholera death-rate.

It is well known by those in charge of the water mains that there is always more sediment in the city pipes when pumping is in progress, and it is generally agreed that, by pumping, the silt at the bottom of the lake is stirred up and carried along with the water supplied to the city. This sediment would irritate the coats of the digestive organs of water drinkers and would thus render them susceptible to cholera.

Another possible explanation of the relation of cholera to pumping is that, when pumping is resorted to, the supply is restricted, and consequently the inhabitants are driven to obtain water from the badly polluted wells that abound in the city. This may be the correct explanation, even though the records of water sent down the channel from Red Hills Lake show that the quantity is the same whether there is pumping or not, there is, however, undoubtedly greater scarcity during the hot weather, due probably to the greater quantity of water used by those whom the water reaches first for drinking, watering and washing, with the result that those furthest away from the source have less at this season than during the rest of the year.

The true reasons, therefore, why cholera closely synchronises with pumping at Red Hills would seem to be three-fold, *i.e.*—

- (1) Shortage of water causing people to resort to wells and tanks.
- (2) Muddy water from Red Hills predisposing to cholera.
- (3) The unfortunate coincidence of (1) and (2) with that period of the year most favourable to cholera.

New works.

6. *New works in course of construction.*—To remedy the above mentioned faults of the existing water supply, the following new works are being constructed:—

- (a) An intake tower located at a point where the water of the lake is deep.
- (b) A new underground conduit to replace the existing open channel.
- (c) Sand filters to purify the water.
- (d) Pure water tanks to store the filtered water.
- (e) Pumps to impart to the water an adequate pressure.
- (f) An elevated tank to ensure the maintenance of a steady pressure in the mains.
- (g) The remodelling, alteration and extension of the distribution system so as to provide all the inhabitants of Madras with an adequate quantity of water under sufficient pressure.

7. *Present position of new works.*—Of these works, the intake tower, conduit, filter beds and pure water tanks are practically completed, the pumping station and masonry foundation and supports of the elevated tank are in course of construction, the pumping machinery has been delivered and erection has been started. The 48-inch steel pumping main is being laid. Contracts have been let for the Steel Tank and its steel supports and for the pipes required for the most important mains and more urgent distributories. These works will now be dealt with in detail.

Detailed Description of Works.

8. *Intake Tower.*—For many years, the necessity of an improved water supply has been recognised. When the Red Hills Tank *bund* was breached

in 1881, the opportunity was taken to construct a masonry intake tower at one of the deepest points of the lake, and to lay two lines of 24-inch cast iron pipes through the tank *bund*.

These pipes will take only about one-third the quantity of water that the new conduit will carry with the same velocity. It had, however, been decided to sacrifice a few inches of head and to retain them, rather than to incur the considerable expense of laying larger pipes and reconstructing the tower.

The tower is situated about 110 feet from the face of the top of the *bund* to which it will be connected by means of a steel bridge. At different levels inlets are provided with valves actuated by machinery situated inside the tower; by their means the purest water—generally situated a little below the surface—can be drawn off whatever the level of the lake may be.

The tower has been built at a point where the lake is deep and with the new intake water may be drawn off to a level 10 feet lower than is now possible. Thus will be rendered available 1,110,000,000 cubic feet more water than can, under present conditions, be taken from the lake without pumping, and a further most important advantage will be secured for the increased storage will obviate the necessity of pumping which at present involves not only extra cost to the Corporation but also danger to the health of the city.

9. *Screening Chamber and Roughing Filter.*—The two 24-inch pipes from the intake tower, after passing through the tank *bund*, terminate in a screening chamber, the supply to which is regulated by two automatic valves which are actuated by floats so as to close when the water rises above the level required to give the requisite flow through the conduit.

The walls of the screening chamber are fitted with movable copper gauze screens— $\frac{3}{32}$ inch mesh—having a total area of 125 square feet through which the water must pass in order to reach the Roughing Filter.

After leaving the screening chamber, the water will enter the *Roughing Filter* at floor level, and rising through a filtering medium consisting of broken stone supported on stone slabs themselves resting on brick piers, it will flow over a measuring weir into the conduit. The quantity of water flowing over the measuring weir will be automatically recorded on a diagram attached to a drum actuated by an eight-day clock. The head will be translated into flow by means of a Hutchinson Recorder. A bye-pass pipe is provided so that the water can be passed straight into the conduit without filtration, when the surface of the lake sinks below the level of the measuring weir.

The Roughing Filter is a brick chamber 150 feet long, 108 feet wide and 8 feet deep. It is divided into two compartments governed by penstocks, so that one half may be thrown out of action for repairs or cleaning while the other half remains in use. Ordinary cleansing will be effected by reversing the flow through the filter.

The filtering medium consists of 3 feet of crushed trap rock varying in size from that which will just pass through a $1\frac{1}{2}$ inch ring at the bottom, to the top layer which will pass through a $\frac{3}{8}$ inch ring and be rejected by a $\frac{1}{8}$ inch ring.

10. *The Conduit.*—The conduit, which conveys the water from the Roughing Filter at Red Hills to the Sand Filters at Kilpauk, is a culvert 7 miles long with an average gradient of 1 in 4,470.

Internally, the conduit is 5 feet wide with vertical side walls 4 feet high to the springing of the arched roof which has a rise of 18 inches. The floor is inverted with a dip in the centre of 3 inches, so that the maximum height is 5 feet 9 inches.

The whole of the internal surfaces of the conduit are coated with cement plaster (1 cement to 3 sand) $\frac{3}{4}$ inch thick, and the outside of the arch is plastered with $\frac{3}{4}$ inch of combination mortar.

When originally designed, it was not intended that the conduit should be subjected to internal pressure. Where depressions are necessary to pass under

water courses, it was proposed that steel pipes should be used. After careful consideration, however, it was decided to construct one continuous masonry conduit and dispense with the steel pipes except for one short length of 50 feet. In those places where the conduit is under pressure, the masonry has been reinforced with barbed wire to take the tension.

The advantages of the new conduit as compared with the open channel are:—

- (1) The conduit will tap the lake ten feet lower than the bottom of the existing channel, thus rendering available, without pumping, 1,100 million cubic feet of water, all of which is below the existing intake, and which at present can be utilised only by undesirable pumping which stirs up, and sends down to Madras the silt lying on the lake bottom.
- (2) There will be no loss of water by evaporation and percolation.
- (3) The carrying capacity of the conduit will be sufficient to supply Madras with 25 gallons of water per head per day for many years.
- (4) The covered underground conduit will render impossible all ordinary contamination, such as that to which the open channel is liable.
- (5) The danger of the slipping of the open channel banks will be eliminated.

11. *Filters.*—There are in all fourteen Filters of the ordinary slow sand type. The filters are arranged in two rows of seven each—it being intended that six filters of each row—twelve in all—should be continuously in operation, allowance being made for one filter in each seven being under repair or being cleaned. Provision has also been made for seven additional filters which will be constructed when required. The conduit which brings the water from the Red Hills is continued round the fourteen filters and is connected to each bed by a 14-inch diameter cast iron pipe controlled by a valve, so that any filter may be isolated for cleaning or repair. Between the two rows of filters runs the filtered water channel to which filtered water from each bed can be delivered through a Glenfield-Jones automatic outlet designed to keep the rate of filtration constant. Each filter is 200 feet long and 100 feet wide, this being a convenient size for cleaning without throwing out too large a filter area at a time.

Below the top of sand level the walls are slightly battered, in order that the sand by its own weight may be packed tightly against the walls and thus prevent the free flow of water between the sand and the walls. For the same reason, the walls are splashed with rough plaster, so as to form a key for the sand. As a further precaution neither the drains nor the broken stone at the bottom of the filters will be taken right up to the side walls. The drains will be stopped a few feet away from the walls; broken stone will be placed round the ends of the drains and the space between the stone and the walls will be filled with sand.

The filtering material consists of clean washed river sand, so screened as to eliminate all material except that which passes through $\frac{1}{50}$ inch mesh and is retained on $\frac{1}{50}$ inch mesh. Under the fine sand layer 26 inches deep will be a layer of coarse sand 4 inches deep itself resting on broken granite stone laid in three layers, each 4 inches deep. The top layer of stone will pass a $\frac{3}{8}$ inch ring and be retained on a $\frac{1}{8}$ inch ring. The layer below this will pass a $\frac{3}{4}$ inch ring and be retained on a $\frac{3}{8}$ inch ring, while the bottom layer will pass a 2-inch ring and be retained on a $\frac{3}{4}$ inch ring.

Below the bottom layer of stones will be brick drains consisting of best pressed bricks laid flat $4\frac{1}{2}$ inches apart and covered by another layer of bricks with open joints. Through these drains, the water makes its way to the main semi-circular drain sunk below the floor of the filter bed. This drain is 24 inches wide, and will be covered by Cuddapah slabs. It will lead to the rectangular filter outlet chamber which will contain a Glenfield-Jones automatic outlet regulator, the object of which is to ensure that the rate of filtration shall be

maintained constant. Each of these regulators consists of an outlet pipe 14 inches in diameter capable of moving up and down inside a larger fixed cast iron pipe which is bolted down to the floor of the chamber.

The movable pipe is fitted with two weirs, each 15 inches long attached to galvanised iron float tanks, so arranged that the outlet will discharge 1,100 gallons per minute. This is equivalent to 152 inches vertical per 24 hours. The apparatus can be set to any maximum below this quantity, and the standard rate proposed to begin with is 8 feet or 96 inches vertically per 24 hours, but this will be subject to modification, should some other maximum rate appear desirable. When the flow tends to increase above this quantity, the floats automatically raise the weir, so that the head over the weirs, or in other words, the quantity flowing through the outlet remains constant, whereas when the flow through the filter tends to decrease owing to the clogging up of the sand by the deposited material, the level of the water in the outlet chamber is reduced and the floats sinking with the water surface—lower the weirs until the head is increased to such an extent as to keep the rate of filtration what it was before. This apparatus insures a constant flow through the filters until the weirs have reached their lowest points when the rate of filtration steadily diminishes and the Superintendent becomes aware that it is necessary to cleanse the filters.

The travel of the telescopic pipe is little more than 2 feet 6 inches. Each outlet is provided with a fixed dial and a moving pointer to show the depth and quantity of water flowing over the weir. A hand wheel actuating a screw is also provided and is so arranged as to allow the outlet pipe to rise or fall freely with floats under normal conditions, but to be capable of raising or lowering the telescopic pipe and thus reducing or increasing the rate of filtration just as in an ordinary non-automatic telescopic pipe regulator.

12. *Pure water tanks.*—The filtered water will flow into three underground covered pure water tanks, each 150 feet square with a depth of 10 feet of water, having a capacity of 1,400,000 gallons each.

The floor consists of 2 feet of concrete and the side walls of brickwork. The roof is supported on brick jack arches springing from steel girders supported on brick cross walls carried by arches springing from granite stone piers. Access to each tank is provided by means of manholes, and vent pipes are provided to allow the free ingress and egress of air which is very necessary, seeing that the water level will be constantly varying.

Each tank is provided with a 30 inch inlet and 30 inch outlet, both fitted with sluice valves so that any tank may readily be isolated for cleaning or repairs without interfering with the working of the other tanks. A scour is also provided for each tank.

13. *Pumping Station.*—From the pure water tanks, the water will gravitate to the suction culvert whence it will be pumped into the corporation mains, an elevated tank being connected with the pumping main, in order to act as a balancing tank between the pumps and the distribution system.

14. *Buildings.*—In designing the pumping station buildings, an endeavour has been made to give them a pleasing appearance and much attention has been paid to a suitable style of architecture. There is no doubt that environment is important and in England, private water companies, whose primary object is to make money, recognise the importance of good buildings. If the pumping station is suitably designed, and if it is in keeping with the machinery it has to house, if it is well ventilated, well lighted, clean, cool, and inspiring both inside and out, then it is likely that the drivers will take a pride in looking after the machinery and in maintaining it clean, polished, and well oiled, perfectly adjusted, and in the best possible condition. The working costs will be reduced and the life of the plant will be increased.

On the other hand if the building is mean in appearance, hot, difficult to keep clean, badly lighted, ill-ventilated, the machinery is sure to suffer. The drivers will take no pride in keeping it up to the highest pitch of perfection, parts of the engines will be allowed to get rusty and dirty, small faults will not be remedied immediately, and in consequence the cost of upkeep will be high and the life of the plant will be short. In this way it is a real economy to provide a station worthy of the machinery it is to house.

The station will be built of locally made bricks. The string courses and arch keystones will be Sholinghur granite, but in general the amount of stone work will be reduced to a minimum, in order to keep the cost as low as possible.

The towers at the four corners should give distinction to the building, and prevent it being dwarfed by the elevated tank. The suction culvert has, for the sake of economy, been kept small, but is of sufficient sectional area to allow the free passage of water to the furthest pump whatever the level in the clear water tank may be.

The height of the chimney will be 150 feet to ensure a good draft with Indian coal. Experience with other plants in Madras has led to the conclusion that higher chimneys are required in this city than in other places where the atmosphere is less humid and where a better quality coal is obtainable.

15. Pumping Machinery.—A contract amounting to Rs. 3,90,000 has been let to Messrs. James Simpson & Co., for the supply of the pumping plant which comprises three High Duty Worthington Direct Acting Engines each capable of delivering 12,000 gallons of water per minute against a maximum total head of 80 feet. Three Babcock and Wilcox Boilers are provided each capable of supplying steam continuously to any two engines working together against a total head of 80 feet.

The machinery is so arranged that any two engines can be worked from any two boilers and that any group of engines and boilers may be worked together and also that any engine or boiler may be cleaned or repaired without interfering with the working of the other engines and boilers.

The guaranteed consumption is 1.75 lbs. of Bengal coal per pump horse power hour which is an extremely low figure. The boilers will be provided with automatic chain grate stokers having an area of 36 square feet.

A Venturi meter will be inserted on the 48 inch pumping main and will be arranged for a maximum registration of 1,800,000 and a minimum registration of 120,000 gallons per hour. A combined recorder will be used to show by diagram the rate of flow at any moment and by counter the total quantity passed. A water level and pump pressure recorder will also be provided, so that complete records will be available for calculating the work done by the plant.

16. Elevated Tank.—An elevated tank is required to maintain a balance between the demand and supply of water to the distributary system. The demand is constantly changing throughout day, and also changes from one day to another. To meet this fluctuation, a tank is required at such a height as will ensure an adequate pressure all over the city and of a capacity sufficiently large to meet small fluctuations in demand.

When the quantity of water pumped is greater than the consumption, the tank will store the excess and will supply it to the city when the consumption is in excess of the quantity pumped.

The tank will be constructed of steel. It is circular in plan 104 feet in diameter and 28 feet deep from overflow level to the flat bottom. It will have a capacity of $1\frac{1}{2}$ million gallons. In order to maintain an adequate pressure all over the city, the tank has been designed with its bottom 37 feet and the top of roof 73 feet above ground level. It is to be built of steel throughout and will be covered by a steel roof. An overflow has been provided consisting of a pipe 36 inches in diameter situated at the centre of the tank and arranged in such a manner as to act as a support for the steel roof, as well as serving its proper purpose of providing an escape for any water that may be pumped into the tank in excess of its holding capacity. It is bell-mouthed at the top to a diameter of 7 feet and will discharge 18,000 gallons per minute with a head of 9 inches and 29,000 gallons with a head of 12 inches. This should be ample, for if the water from the town were cut off altogether, and two pumps working together were delivering at their maximum rate, the quantity entering the tank would be 24,000 gallons per minute or 5,000 gallons per minute less than the overflow will discharge with a 12 inch head.

As already stated, the tank is strictly speaking a balancing tank and only the excess or deficiency pumped enters or leaves the tank. Thus only a small proportion of water supplied to the city will pass through the tank and therefore one

pipe is sufficient to act as both inlet and outlet. It will take the form of 36-inch diameter steel pipe branching off the 48-inch pumping main.

17. *Tank Supports.*—The tank will be supported by an external ring of brick piers and arches while steel stanchions surrounded with concrete will be used for the central supports in order to minimise the weight which, if only brick supports were used, would be greater than the safe limiting pressure on which the foundations rest.

The steel floor of the tank will rest upon steel beams supported by piers and arches. A principle followed in the design of this tank has been to leave exposed as little metal work as possible, thus not only the stanchions but also the floor beams will be encased in concrete, the upper surfaces of these casings constitute the actual supporting floor of the tank in the form of long flat tablins separated by channels. The floor plates of the tank will be arranged in such a manner that their longitudinal joints will come over the centres of the concrete channels and can therefore be riveted up with ease as a protection against corrosion, the bottom of the tank itself will be coated with 1-inch of cement plaster.

18. *Load on Foundations.*—The whole area occupied by the elevated tank, pumping station, filters, etc., is covered by a layer of black clay which would not form a satisfactory shallow foundation, as it is liable to contract and crack during dry weather and to swell during the wet season. In various parts of Madras the expansion and contraction of a similar clay has caused serious cracks in numerous houses. At a depth of eight feet, however, there is a sandy loam on which the tank may be safely founded. The load on the foundations has been restricted to $1\frac{1}{2}$ tons per square foot.

Experience has proved this to be a safe limit, and an experiment made by loading two stones, each 4 square feet in area, with $2\frac{1}{2}$ tons per square foot has confirmed the teaching of experience.

19. *Load on Brickwork.*—Tests made at the Madras Engineering College on twelve samples of Madras bricks gave the following mean results:—

	Hand-moulded stock bricks. 9'28" x 4'18" x 2'60."	Machine pressed bricks. 8'95" x 4'23" x 2'88."
Load at which first crack appeared—total tons.	10'2	8'1
Stress tons per sq. ft.	38'6	30'9
Maximum load : Total tons	29'1	25'9
Stress tons per sq. ft.	109'6	100'1

These strengths refer to bricks tested separately, they are much less than usually obtained by testing good class English bricks. Now the resistance per square foot of high piers to crushing is much less than that of the individual bricks tested separately. Furthermore, a factor of safety of at least 4 should be allowed for the piers of so important a structure, such as this tank. Bearing these points in mind, and after very carefully considering the matter, the load on brickwork in special mortar has been limited to 4 tons per square foot.

20. *Load on concrete.*—Clean unweathered Pallavaram stone, such as is easily obtainable, when mixed with Portland cement mortar makes a very strong concrete. The strength of this material is well known and a limiting stress of 7 tons per square foot, as adopted in this design, may be allowed without risk of failure.

20.-A. *Total weight of materials and water:—*

Steel-work	...	...	...	598'0 tons.
Masonry	...	...	...	9,723'0 "
Water	...	...	...	6,550'0 "
Total	...	...	...	<u>16,871'0 "</u>

Load on foundations :—

Total on foundations ...	...	...	16,870 tons.
Area of concrete base ...	...	...	11,500 sq. ft.
Pressure per square foot ...	...	...	1,460 tons.

Load on stanchions :—

Maximum load on cap of one stanchion ...	...	...	63 tons.
Cross sectional area of steel in stanchion ...	...	...	25.85 square inches.
Least radius of Gyration ...	...	...	3.4 inches.
Total Load on Piers ...	...	...	8,827,530 lbs.
Area of Piers ...	...	...	866.7 sq. ft.
Pressure per square foot ...	...	...	10,185 lbs = 4.54 tons.

21. *Method of constructing works.*—Before construction was commenced, the question of the agency by which the waterworks should be carried out was very carefully considered, and it was eventually decided that the work should be divided into small sections, so that it might be executed by local contractors. This was thought preferable to importing outside contractors with up-to-date plant, machinery, and methods of construction, such as are used in Europe, for it insured that the money spent on the work should as far as possible be paid to local firms, and further it was considered that the work would be done more cheaply, although the time taken would probably be longer. The results have confirmed these anticipations and the employment of local contractors has been justified so far as the cost has been kept low, but on the other hand, the rate of progress has been much less than that it would have been, if some large European firm had been entrusted with the whole of the works.

The whole of the excavation and masonry work has been executed by local contractors. The necessary excavation was taken out by the ordinary Madras method. The soil—mostly clay or sand loosened by mamoties and deposited in baskets which were passed up from cooly to cooly and finally deposited just clear of the excavation. Very little timber was used, but, where necessary, the sides of the trench were sloped back. Slips were frequent and delayed the work considerably, but owing to the cheapness of labour, the contractors found it more economical to allow the slips to occur rather than to timber the trenches—an art not understood in Madras—and suffer the considerable loss by theft that is found to occur wherever timber is used.

The only place where proper timbering was employed was at the pumping station suction culvert where excavation was taken some 6 feet below sub-soil water level. Here it was necessary to use two settings of timber consisting of runners, wallings and struts, in order that the ground which was to support the engines should not slip. This timber had to be kept tight against the excavation in a manner that it was impossible to get contractors to do in Madras, and in consequence the work was carried out departmentally as was all the underground work of the pumping station.

22. *Dealing with water.*—It was found very difficult to make the local contractors understand that water can easily be led, but can be forced only with great difficulty, and it was only by constructing drains with his own hands that the writer was able to impress upon the contractors that sub-drainage is absolutely necessary in wet grounds, where masonry foundations have to be put in well, rapidly and cheaply. In constructing the conduit, the excavation was taken out slightly wider than required for the masonry, and the side channels thus provided were used for leading the water to sumps formed in the sides clear of the work. From these sumps the water was raised to the surface generally by means of picottahs, each being capable of lifting some 60 gallons per minute. Three or more of these picottahs were frequently working at one face at the same time. Where there was more water than picottahs should deal with, oil engines and centrifugal pumps were used, 4 inch pumps being usually employed. A very useful set was a 10 horse power Crossley Oil Engine and belt driven 4-inch centrifugal pump mounted on a single substantial four-wheeled trolley, so that it was readily moved from point to point. This plant was capable of raising 350 gallons of water per minute with a suction varying from 10 to 20 feet and a total head of 30 feet. It proved very useful at the pumping station suction culvert where excavation was carried some 6 feet below the water level.

23. *Conduit.*—In constructing the conduit, the concrete foundation was first put in, then the brick invert and two feet of side walls. At this stage the inside face of the work done was plastered, for it was found that, if left exposed, the falls of earth which occurred at short intervals rendered it very difficult to get the brick work and concrete as perfectly clean as is requisite for the satisfactory application of cement plaster. The remainder of the side walls and arch could then be constructed at leisure without much danger of damage due to slips or rain. On some occasions, however, after heavy rains, there would be a bad slip of the untimbered earth sides which would carry away considerable lengths of the side walls. Owing to the lateral support afforded by the arch no damage ever occurred to the completed conduit due to this cause. When the side walls had been completed the timber centres were set for the arches. They were made in lengths of 12 feet and consisted of two parts. A rectangular frame work running on wheels which supported the centre proper. The centre was adjusted to the correct level by means of screws. When the arch had set, it was lowered by the same screws and the whole structure was drawn forward into position for the next length. With the "combination" mortar used, it was possible to strike centres in 24 hours or, if necessary, even less. After the centres had been struck, the plastering of the interior surface of the conduit was completed, light being obtained through holes left in the arch which were subsequently covered with Cuddappah slabs set in mortar. In addition to these holes, light also found access to the conduit through man-holes, which are placed at every change in direction and in straight lines at every 1,000 feet.

24. *Filters.*—No special difficulties were encountered in constructing the filters. The foundation of combination mortar concrete was laid continuously in three layers over the whole area to be covered by one set of seven filters, and the brick side walls and division walls were built as soon as the concrete had been laid.

On the top of the combination concrete, a layer of brick-on-edge covered with cement plaster was laid in one filter. This proved slow on account of the difficulty experienced by the contractor in obtaining bricks and was also expensive. In order to increase the speed of the work, the floors of the remaining filters were covered with a layer of cement concrete, 4-inch thick, which was laid in strips 10 feet wide across the width of the filter, an asphalt expansion joint being provided between each strip. This was done because the filters could not be filled for some time after completion. During this time they were exposed to a hot sun by day, and the result of the variation of temperature in so large a mass of concrete would inevitably have been numerous cracks. The method adopted to prevent these has been entirely successful and a perfectly water tight bottom without any cracks has been secured.

25. *Pure water tanks.*—The foundation of the pure water tanks was laid below ground water level, and, owing to the contractors not understanding the proper way of dealing with water, considerable difficulty was met with, and the writer had personally to construct rubble drains to convey the water to sumps where it was raised to ground surface by means of piccottahs and pumps. When once the method of draining had been properly applied, the concrete was put in without any difficulty. The construction of the walls and the roof calls for no special remarks.

26. *Pumping station.*—Owing to the difficulty which had been experienced in getting the contractor to deal properly with the water met with in the foundations of the pure water tanks, it was decided that the underground work of the pumping station should be carried out departmentally, for the bottom of the suction culvert went some 5 feet below the bottom of the pure water tanks foundation. The water percolating through the sand and clay met with in the foundation formed a quick-sand which was difficult to deal with, and made progress necessarily slow, but with patience the difficulties were overcome, and when the work had been carried above ground water level, no further trouble was encountered.

MATERIALS USED IN CONSTRUCTION.

As far as possible, local materials have been utilised in all of the works. Bricks, lime, sand and stone in fact, everything except Portland cement has been obtained from local sources.

27. *Bricks*.—Bricks were burnt at the site of the works wherever suitable clay could be obtained. The type most used was an improved "country" brick measuring $9" \times 4\frac{3}{8}" \times 2"$. It was insisted that this brick should be hard, sound, well burnt, true in shape, uniform in size and free from lime, fire cracks and every other imperfection. The bricks were made sometimes on smooth platforms on the ground, and sometimes on rough wooden tables; the moulds were lined with iron or brass. The percentage of sand to clay was about 33 per cent. These thin bricks were allowed to dry in the open air and were subsequently burnt in country kilns containing one to two lakhs each. Only about 60 per cent. of the bricks moulded were used in the works, the remainder being broken, under-burnt, or otherwise imperfect. The broken, but well burnt bricks were pounded into *surki* and were used in the combination mortar. The under-burnt bricks were largely sold to builders as second class bricks.

Before the water works were started, it was explained to the contractors that a considerable saving in mortar and labour in laying would be effected by using a thicker brick, but for a long time, the contractors were of opinion that thin brick would be more economical on account of it being less costly to manufacture. Towards the end of the work, however, 3 inch bricks were largely used and there is little doubt that better and cheaper work can be obtained by using a brick of this thickness. The principal disadvantage of the thicker brick is that with very wet clay such as is used in the hand moulds, considerable time is required to dry the bricks, and, if they are left in the open, they become damaged; consequently it is necessary to erect drying sheds. These, however, need only be tatty sheds with bamboo supports and quite inexpensive.

No kind of brick which is obtainable in Madras is suitable for resisting the eroding action of running water, and therefore all internal faces of the conduit have been coated with Portland cement plaster (1 cement, 3 sand). This makes an excellent smooth surface, which affords very little resistance to the flow of water.

28. *Sand*.—Sand was obtained from river beds where it is deposited by the monsoon rains. It is formed by the disintegration of igneous rocks found in land and is generally clean, sharp and of good quality.

29. *Lime*.—Lime was made from shells obtained from Irukum and other places, some 23 miles to the north of Madras, whether they are brought by canal boats. Sometimes they were burnt when purchased, at other times they were burnt by the side of the work, but at all times they were slaked at the works depôt in the presence of the overseers. Before use, the slaked lime was screened through a fine mesh sieve. The lime thus obtained is very fat, being practically pure calcium carbonate; it was very rarely used except in conjunction with *surki*.

30. *Surki*.—*Surki* was made by pounding freshly burnt bricks into powder. Only that portion was used which passed through the screen of 100 meshes to the square inch. The average fineness of this *surki* powder as tested by experiment is such that 100 per cent. passes through a sieve of 100 meshes to the square inch inclined at angle of 45 degrees.

90 per cent. passes through a sieve of 400 meshes per square inch.

84	"	"	"	of	900	"	"	"
61	"	"	"	of	1,596	"	"	"
51	"	"	"	of	10,000	"	"	"

31. *Portland Cement*.—Portland cement was imported by the Corporation direct from England and was supplied to the contractors as required in barrels containing about 375 lbs. of cement which as the result of experiment was taken as having a volume of $4\frac{3}{4}$ cubic feet.

32. *Stone*.—The stone used in concrete was a crushed trap-rock locally known as "granite," obtained from quarries at Pallavaram, some 12 miles from Madras. It is an excellent hard, tough stone. It is however, very costly to dress, and for chiselled work a light coloured granite-like stone obtained from Sholinghur was used.

33. *Mortar*.—Where running water was encountered, Portland cement mortar in the proportion of 1 cement to 3 sand has been employed, but in nearly all underground work, and in a great deal of the work above ground,

"combination" mortar has been used. This mortar is usually composed of 1 part Portland cement, 1 part of shell lime, $1\frac{1}{2}$ part *surki* and 6 parts of sand, all measured by volume. It was adopted as the results of experiments to obtain a cheap mortar. The usual mortar used in underground work in Madras is lime *surki* mortar, composed of one part lime, one part *surki* and one part sand. If given sufficient time to set, very good results are obtained from this mortar, but its setting time is so long, that it was out of the question to use it for most of the water works where the centres had to be struck and the work had to be covered in very soon after putting in position.

The "combination" mortar sets quickly and centres can be struck within 24 hours after finishing the work. It is of about the same strength as cement mortar (1 cement to 3 sand) and is very much less in cost, the contractor's price for brickwork or concrete being about Rs. 20 less per 100 cubic feet where combination mortar is used than where 1 to 3 cement mortar is used.

DISTRIBUTION SYSTEM.

34. *Essential Requirements.*—The additions and improvement to the distribution system have been designed to ensure the fulfilment of the following essential requirements :—

- (1) The supply of all consumers with an adequate quantity of water continuously throughout the day.
- (2) The maintenance of a sufficient pressure throughout the distribution system.
- (3) Perfect and rapid circulation of water throughout the entire system.
- (4) Reasonable protection against fire.
- (5) Means of detecting and stopping waste in a systematic manner.

35. *Faults of existing system.*—The existing system fails in all these respects. The supply in many parts of the town is inadequate. It is insufficient for the reasonable requirements of the inhabitants, and over a considerable area it fails altogether during those hours of the day when water is most wanted. The pressure is deficient almost everywhere. In most of the thickly populated areas the water available is insufficient to afford reasonable protection against fire. There is a great deal of waste, but no means exist for systematically detecting and stopping it.

That these faults should exist is not to be wondered at, for the present system was laid out some forty years ago, and since then the population of Madras City has increased by 120,000. To supply this greatly increased population, a large number of small distribution pipes have been laid and the consumption has increased to so great an extent that the leading mains are quite incapable of supplying sufficient water to feed the greatly increased number of small distributaries.

The method of procedure adopted in preparing the design for reinforcing the existing system was to ascertain what quantity of water is required for different parts of the city, what the existing system is capable of supplying and then to determine what additions and alterations are needed to make efficient the existing inadequate system.

36. *Population to be supplied.*—The first step in planning the distribution system was to ascertain as precisely as possible the population to be supplied in the different districts of the city. In considering this question, it was important to decide what future increase in population should be provided for, or in other words to what extent the capacity of the pipes should be enlarged in order to meet future increased demands without laying an undue burden of cost upon the present tax-payers. It is anticipated that such loans as are required to defray the cost of this work will be subject to repayment over a period of from 30 to 50 years according to the nature of the

works, and thus it was considered that the distributory system should be sufficient for the needs of the consumers at the expiration of that period. The pipe system was therefore designed so as to suffice for all parts of the city up to 1961.

37. *Population of Madras City, as a whole.*—In order to determine the population to be supplied a study has been made of the census returns from 1871 to 1911. The following table gives figures for the City of Madras as a whole:—

Date of Census.				Total area in acres.	Population of Madras City.	Increase in 10 years.	Percentage increase in 10 years.
1871	...	...	...	17,165	393,920	...	...
1881	...	...	...	17,165	398,777	4,857	1.23
1891	...	...	...	17,467	450,640	51,863	13.00
1901	...	...	...	17,280	509,346	58,706	13.00
1911	...	...	...	...	517,335	7,989	1.57

38. *Populations of Divisions.*—In order to determine the sizes of the mains required to supply the different divisions of the city it was necessary to ascertain not only the probable increase in the population of the city as a whole, as given above, but also the probable rate of increase in the population of each division and sub-division which is supplied by a separate main.

After a careful study of all information available, it was decided to provide for populations in the different divisions as shown in the following table:—

No. and name of Division.				Population in 1911.	Estimated increase in 50 years.	Population in 1961.
1.	Tondiarpet	...	...	75,986	23,514	99,500
2.	Georgetown, West	...	...	86,584	8,516	95,100
3.	Georgetown, East	...	...	54,833	4,314	59,300
4.	Perambur	...	...	24,981	27,619	52,600
5.	Vepery	...	...	95,172	24,828	120,000
6.	Nungambaukam	...	...	26,929	9,571	36,500
7.	Triplicane	...	...	98,254	13,746	112,000
8.	Mylapore	...	...	54,443	30,557	85,000
Total				517,182	142,665	660,000

39. *Quantity of water to be supplied per head.*—The average daily consumption has been taken as 25 gallons per head per day. This is the quantity recommended by the Commission appointed by Government in 1890, and has formed the basis for the design of the water-works now in course of construction. Twenty-five gallons per head per day is considered necessarily high by some persons who point to the much lower recorded consumption in the mofussil towns of this Presidency, but enquiries have led to the conclusion that the consumption in these towns is not a reliable guide to the quantity of water which should be supplied to Madras, because in mofussil towns there is, in many cases, scarcity of water which has to be replenished from wells. Judging by the consumption in Bombay and Calcutta, 25 gallons per head per day is certainly not too high, and, if there is not to be a scarcity, every precaution must be taken to prevent waste and misuse. While some persons consider that 25 gallons per head per day is more than enough, others, on the other hand, argue that the supply should be much greater than 25 gallons per head per day. The quantity of water available from existing sources as estimated by the writer from a careful study of all available statistics is 35 gallons of water per head per day for a population of 660,000, provided all irrigation supplies were stopped, but as in the absence of exact measurements this estimate had to be based largely on hypothesis, it is not advisable to count on an available supply of more than 25 gallons per head per day, until measured flows have proved it safe to estimate on a larger quantity.

40. *Maximum rate of supply.*—Twenty-five gallons per head per day is the assumed daily average throughout the year. But at certain times of the year, especially during dry hot weather, the average is likely to be considerably exceeded. In England this excess is found to be 20 to 40 per cent. on a number of days: and the writer is of opinion that for Madras the addition of 20 per cent. to the 25 gallons average will not give too high a maximum during the hottest part of the dry weather, when well supplies diminish, streams dry up, and large quantities of water are used for gardens, etc. A higher figure is not taken, because during the hottest weather a number of large consumers of water are out of Madras, at hill stations, in Europe and elsewhere.

Experiments which the writer has carried out on the flow of sewage throughout the day show that at the present time the maximum is about $1\frac{2}{3}$ the mean flow. The variations of sewage flow may be taken as a measure of the variations of water consumption.

But up to the present it has been impossible to determine the real maximum by experiment, because the people cannot get as much water as they need, nor can they take it as quickly as they want. It is a common sight in Madras to see a dozen people waiting their turn at a tap, but, if house connections become practically universal, each of these twelve persons will draw from a separate tap, and twelve taps will be running instead of the one only. $1\frac{2}{3}$ rd to 1 is therefore too low a figure to be taken as the relation between the maximum and average for any day, and 2 to 1 has been taken to express this relation.

From these considerations then it is concluded that to the average annual daily water consumption 20 per cent. must be added to allow for the maximum daily consumption, and as just pointed out, the 120 per cent. thus obtained should be doubled to assure that there shall be sufficient water during the hours of maximum demand in the morning and evening. We thus arrive at a maximum consumption equal to 2.4 times the average. Even this figure does not allow for water required for fires, new-moon days and special festivals when especially large quantities of water are used for baths and house cleaning.

To cover such cases it will be reasonable to plan the distribution system so as to be capable of supplying three times the average daily demand. This has been done in the scheme now about to be executed. The writer is convinced that this size is not too large for the pipes newly laid, for account must be taken of the decrease in carrying capacity which occurs with usage.

41. *Pressure to be maintained.*—The minimum pressure maintained in mofussil towns in this Presidency is understood to be 10 feet. This is exceedingly low, compared with the usual practice in Europe and America where the

least pressure is usually about 50 to 80 feet. In Bombay the lowest pressure in any district is 50 feet, and in many districts it is between 100 and 150 feet. Calcutta has just completed a scheme costing some thirty lakhs of rupees to ensure a pressure of at least 40 feet at all times in every part of the city. In these circumstances, the writer is of opinion that the minimum pressure in Madras at the average rate of supply of 25 gallons per head per day should be about 50 feet above ground level at the ends of principal mains, and additions and alterations to the existing system have been worked out to ensure this pressure.

42. *Minimum size of pipes.*—The smallest new pipe will be 4 inches in diameter. This is the least which should be allowed in the distribution system, but owing to the expense of replacing all the existing 3-inch pipes by 4-inch, it is proposed to leave in the 3-inch pipes wherever they are not too small to supply domestic requirements. At the same time it is recommended that whenever 3-inch pipes are taken up for cleaning or other purposes, they should be replaced by pipes at least 4 inches in diameter, for 3-inch pipes very quickly become choked with dust and sediment, and require frequent cleaning, they are also quite inadequate for fire extinguishing purposes. Every pipe less than 3 inches in diameter will be taken up and replaced by a pipe at least 4 inches in diameter.

43. *House Services.*—Connections will be allowed only to pucca houses that are assessed at or above a value to be settled by the Standing Committee. Mud huts and other poor class dwellings will be supplied by means of public fountains.

It is very important that house services should not be a source of waste or misuse of water. One method which is being advocated for minimising waste is to limit the number of connections. The writer however, considers that connections should be given to every pucca house and waste will therefore be curtailed by—

- (1) adopting a suitable type of connection,
- (2) house to house inspection.

Another method would be by metering every water service, for this would be too expensive and not particularly satisfactory in the case of the poorer type of houses. It is therefore proposed to follow the plan first proposed by Lieutenant-Colonel King, when Sanitary Commissioner to the Government of Madras and to adopt two classes of connections, namely, "first class," and "second class". The second class, which will apply to the bulk of the population will enable a householder to have his own taps provided they are placed in such positions that they can at all times be inspected by the municipal staff. Usually, such taps would be immediately in front of the house, or in the verandah, and could, by a simple arrangement of an iron wire gauzefaced box, capable of being locked, be absolutely protected by the owner. Anyone desirous of having a supply which is not open to inspection without notice will have to pay for a first-class service, which will be subject to the following conditions:—

- (1) The householder will be required to hire water meters placed at his disposal by the Corporation, to adopt specified fittings, and to secure approval of the position of pipes and taps.
- (2) He will obtain a free supply of 163 gallons per month for every rupee of rent with a minimum free allowance of 3,000 gallons per month.
- (3) A charge of 12 annas per 1,000 gallons will be made for all water used in excess of the free supply.
- (4) A charge will be made of Rs. 10 per annum for every tap.

It is believed that by the adoption of this method of house service, everyone in the city will have all the water which he legitimately requires, and that it will at the same time, tend to reduce waste to a minimum.

44. *Fire protection.*—A fire protection supply differs from a domestic supply in that a large quantity of water has to be concentrated at one point in a short time, instead of the uniform distribution which is required for a domestic supply. This concentration entails larger pipes, and, to provide perfectly for fire extinguishing purposes, no pipe less than 6 inches in diameter should be laid. The extra expense involved by adopting this size of pipe as a minimum would be very great, and would not be justified in the case of Madras where fires are fortunately of rare occurrence. Everything should be done, however, to ensure that the best use is made of the system available. Owing to the net work principle adopted, the distributory pipes will be supplied from both ends, and the carrying capacity will be doubled as compared with pipes supplied from one end only. In the built-up city areas hydrants will be placed at every street intersection, and should these be more than 300 feet apart, intermediate hydrants will be inserted. There should be some 4 to 6 hydrants available for any fire within the closely built-up areas. If hose pipes are connected on to each hydrant, and brought to a portable tank close to the fire, at least 2 fire engines should be able to draw a full supply. Hydrants will, wherever practicable, be fixed on the leading mains, which will provide an ample supply. Further, in front of all important public buildings the mains will be at least 6 inches in diameter, and in certain cases special means for fire protection will be adopted.

45. *Provision for special cases.*—In the case of large or important buildings, such as Government buildings, hospitals, record rooms, and the like, special precautions should be taken by those responsible for the buildings. Amongst suitable appliances may be mentioned, private hydrants, automatic sprinkler installations, drencher installations and open tanks, at ground level.

46. *Prevention of waste and leakage.*—The consumption which has been provided for, namely, 25 gallons per head per day is very small when compared with that of Bombay, 40 gallons per head per day and Calcutta's filtered water, 27 gallons, plus, unfiltered water, 21 gallons, equals 48 gallons per head per day. In Madras there are few factories and it is unlikely that the consumption will be as great as in either of these cities, but it is obvious that no precaution should be omitted to prevent waste if the supply is to meet the demand; especially as in Madras, there are numerous leaky joints and many unsound pipes. Considerable leakage undoubtedly takes place even with the existing low pressure supply. With the improved water-supply under increased pressure, the waste will be greatly increased. The methods of avoiding waste in house services have already been described. To prevent waste in the main and distributory pipes it has been decided to divide the city into 150 areas, each governed by waste-water metres. The metres to be laid at the same time, as new distributory pipes. In addition, the following steps are being taken :—

- (1) To fit to every public fountain waste-not taps of the limited discharge type.
- (2) To close as many garden taps as possible, to keep a register of such as are allowed, to inspect them regularly, and if the taps are used for other than domestic purposes, then to take action. The argument in such a case would be that if water supplied for domestic purposes be used for non-domestic purposes, that it is mis-used within the meaning of the Municipal Act.
- (3) To print and distribute widely pamphlets in English, Tamil, Telugu and Hindustani pointing out the evils which result from waste and mis-use of water.
- (4) To obtain the co-operation of the police in stopping mis-use and waste, a few convictions and punishments on this account would exercise a strongly deterrent influence on those persons who, through carelessness or thoughtlessness, are responsible for a great deal of waste.

The principal mains as they will be in the new distribution system when completed, are shown in plate 8 where the existing mains and the areas that they will supply are shown in blue, while the new mains and the areas supplied by them are shown in red.

47. The following statement gives the number of pipes included in the new distribution system.

Diameter of pipes.	Existing pipes.	Pipes to be removed.	Pipes to be retained in scheme	New pipes to be laid.	Pipes to be relaid.	Total length of pipes when the scheme is completed.
Inches.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1½	1,160	1,160	...	...	...	...
1½	2,850	2,850	...	...	...	...
1½	6,640	6,640	...	...	...	...
2	180,580	180,580	...	...	...	...
2½	76,120	76,120	...	...	...	...
3	135,570	24,370	111,000	...	...	111,200
4	155,300	5,500	149,800	536,410	2,750	688,960
5	35,550	1,750	33,800	26,370	880	61,050
6	61,170	4,800	56,370	11,808	2,400	70,578
7	81,130	1,750	79,380	18,060	880	98,320
8	9,310	...	9,310	3,265	...	12,575
9	13,440	1,750	11,690	5,270	880	17,840
10	26,280	...	26,280	8,300	...	34,580
12	23,360	...	23,360	12,750	...	36,110
14	24,570	245	24,325	3,160	220	27,705
15	300	...	300	...	...	300
16	8,900	5,605	3,295	3,755	5,045	12,095
18	25,250	7,250	18,000	9,495	6,525	34,020
20	2,170	...	2,170	5,610	...	7,780
21	8,650	...	8,650	...	...	8,650
22	3,700	...	3,700	...	...	3,700
24	4,160	...	4,160	3,700	...	7,860
27	11,750	...	11,750	11,975	...	23,725
30	1,300	...	1,300	14,795	...	16,095
33	...	...	...	300	...	300
36	3,750	...	3,750	6,110	...	9,860
42	4,200	...	4,200	13,759	...	17,959
Totals in feet.	907,160	320,370	586,790	694,892	19,580	1,301,262
Totals in Miles.	172	61	111	132	4	247

These lengths are exclusive of the proposed new 48-inch steel main which, with its connections to existing mains, will have a total length of 3,230 feet.

Description of works.	Estimated cost.	Expenditure to date.	REMARKS.
	Rs.	Rs.	
<i>Main Supply Works—contd.</i>			
Subsidiary buildings	20,000	9,000	Drivers' quarters completed. Land acquired.
Land, Fencing round Filter Beds, etc. ...	60,000	21,000	
Stores Suspenses Account	...	37,000	
Establishment	2,07,000	1,84,000	
Contingencies and Unforeseen works ...	68,000	33,000	
Inspecting and Testing, etc., in England...	72,000	35,000	
<i>Distribution Works.</i>			
Connections to existing and new systems at Kilpauk Shaft.	20,700	...	} Tenders for a large number of pipes, valves, etc., under consideration.
Pipes and special valves, meters laid complete including labour and material.	28,38,712	22,000	
Masonry works connected with Distribution Scheme.	2,65,170	...	Not yet started.
Contingencies	82,268	...	
Total ...	62,79,500	19,30,000	

PLAN SHEWING CATCHMENT AREAS FROM WHICH RED HILLS TANK IS SUPPLIED

PLATE No. 18

SCALE 1 INCH = 4 MILES

EXPLANATION

Area Draining to River Kortalar above Tamarappakkam Anicut coloured Yellow thus	837 sq. miles.	Total 977 sq. miles.
Area Draining to Rivers Kankal and Jousikal which deliver into Channel supplying Cholavaram Tank coloured Green thus	106 sq. miles.	
Area Draining direct to Cholavaram and Red Hills Tanks coloured Red thus	34 sq. miles.	
Area Draining to River Kortalar but diverted to River Cooum coloured Violet thus	268 sq. miles.	

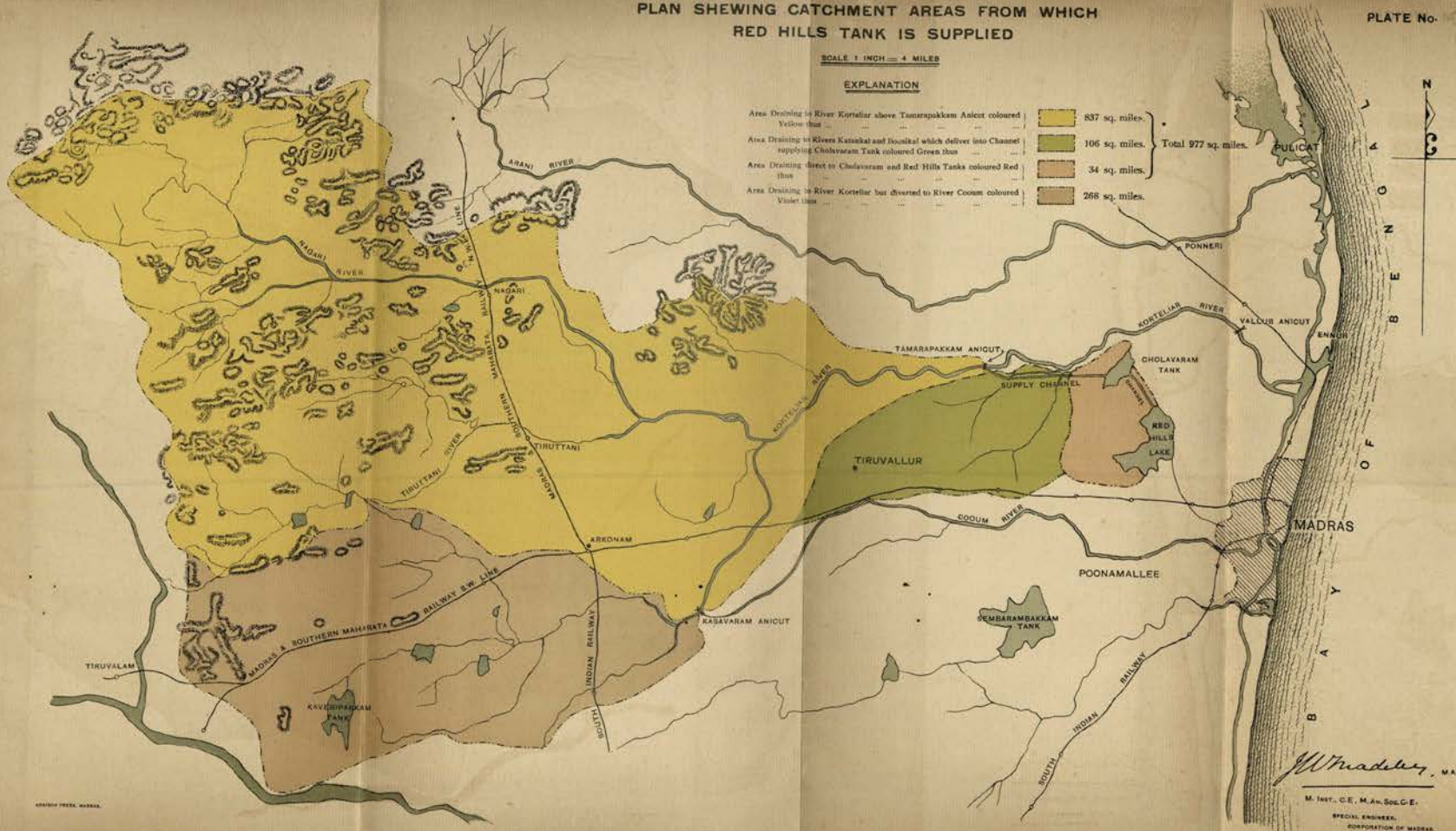
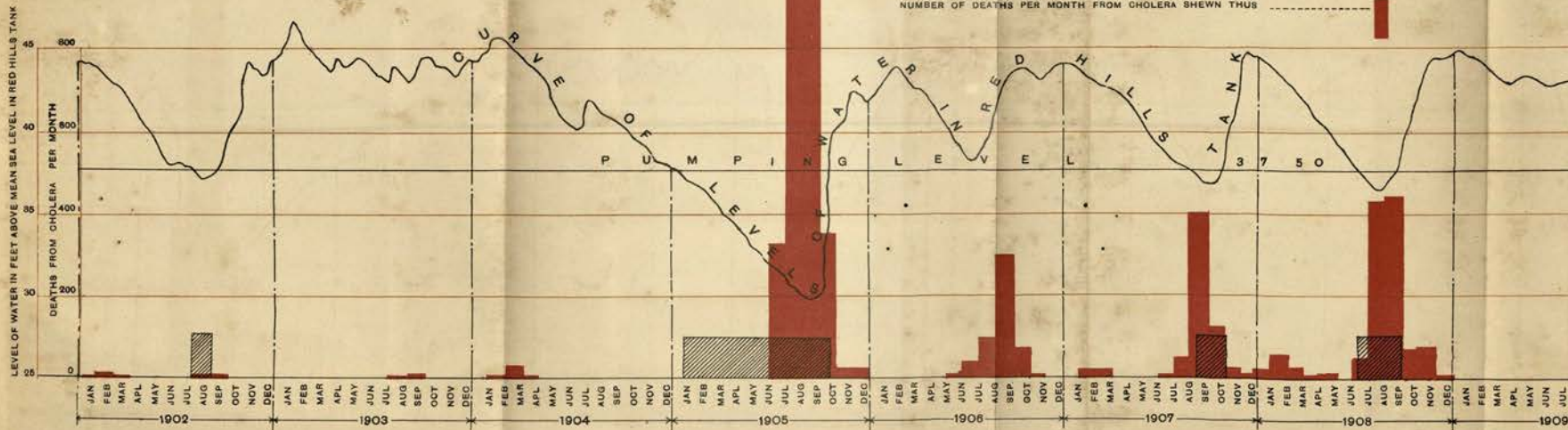
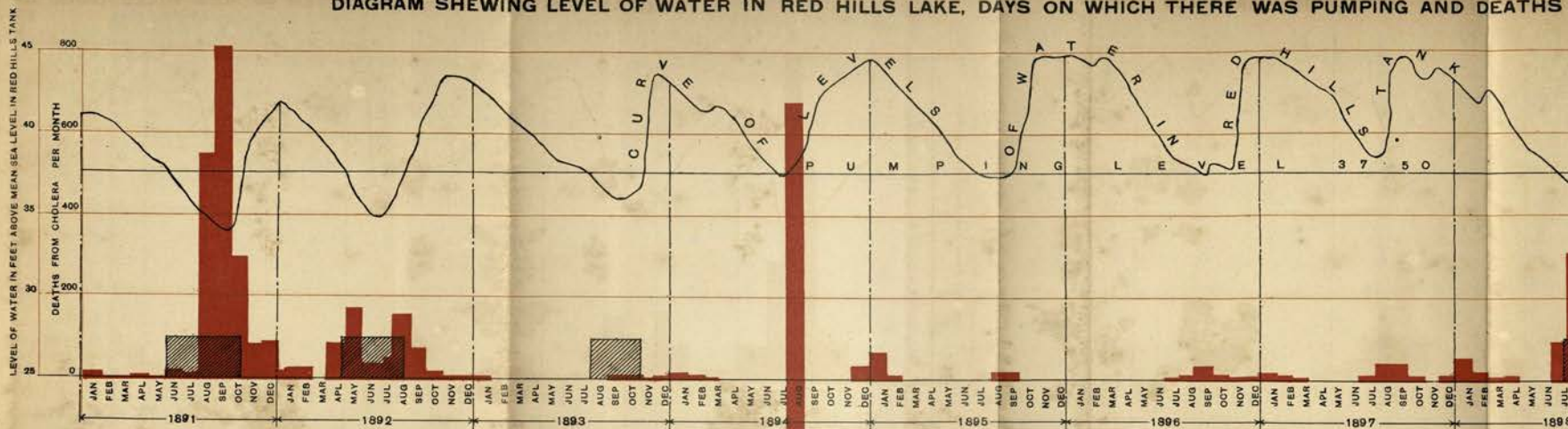
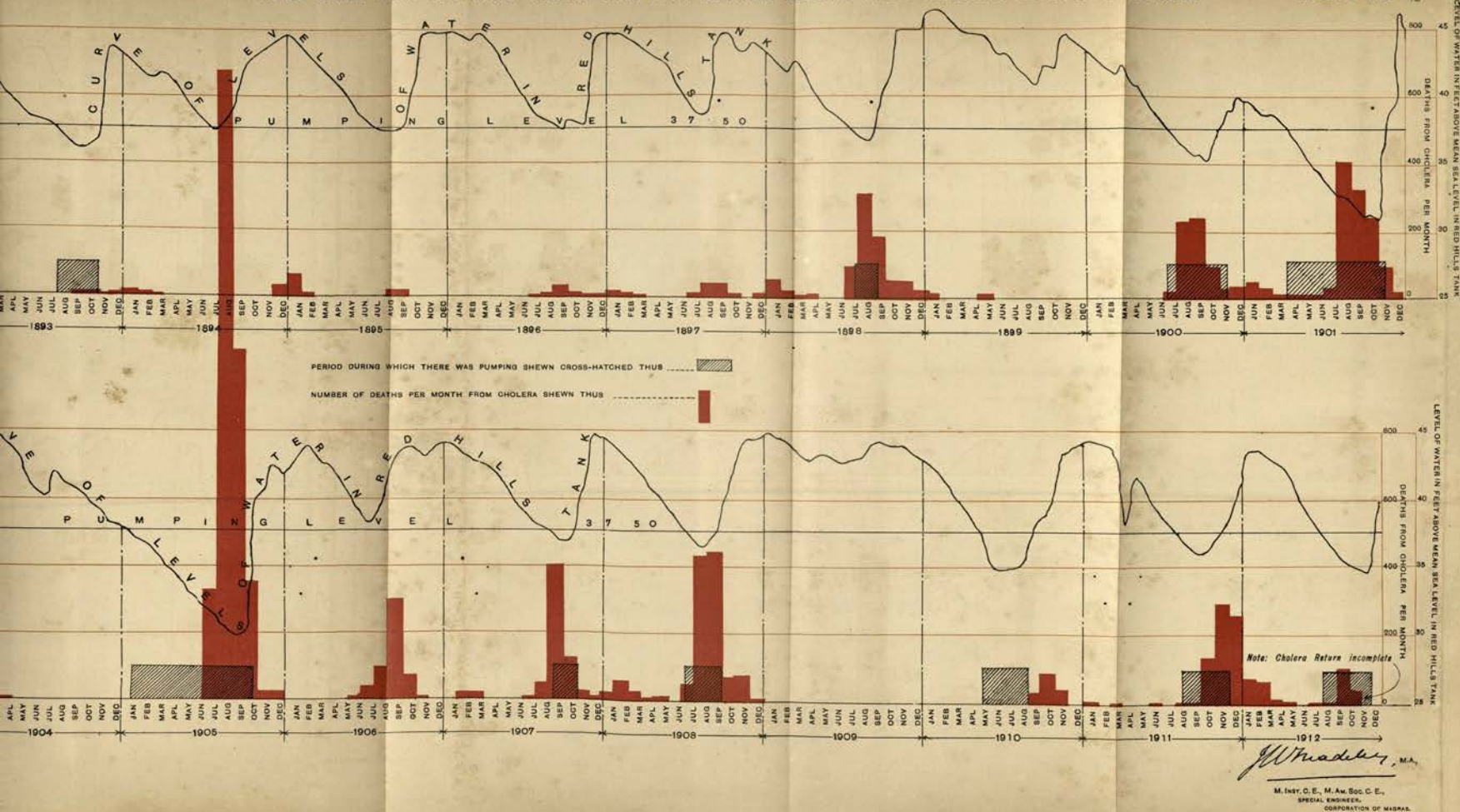


DIAGRAM SHEWING LEVEL OF WATER IN RED HILLS LAKE, DAYS ON WHICH THERE WAS PUMPING AND DEATHS





THE WATER-SUPPLY OF CONJEEVERAM.

The ancient and historic town of Conjeeveram lies about 45 miles to the south-west of Madras in the district of Chingleput. The town is not of much commercial importance, and in point of resident population it does not rank high among the larger towns of the Presidency. It, however, contains many Hindu shrines to which devotees are attracted from as far north as Benares and as far south as Rameshwaram. During the grand festival, which is so-called because of its magnificence as compared with the other festivals in Conjeeveram, and which lasts 10 days in the year, the population swells to more than double the normal population. The rôle played by large centres of pilgrimage in engendering and spreading epidemic diseases like cholera is well-known. The Health Officers of the City of Madras have time after time traced the first victim of an outbreak of cholera in the City to persons, who had just returned after attending a festival elsewhere. The sanitary well-being of a place of pilgrimage is a matter of vital importance, not only to the town itself, but to the whole country from every part of which the votaries to its shrine are drawn. It is to this circumstance that Conjeeveram owes the introduction of a water-supply in the town, before many a larger town in the Presidency had been similarly equipped. It was one of the first schemes, the investigation of which was undertaken in 1890 on the creation in that year of the post of the Sanitary Engineer to the Government of Madras.

In November 1890, at the request of the Collector of Chingleput, the author, in his capacity as Assistant Sanitary Engineer to the Government of Madras, was deputed to inspect Conjeeveram and report on the subject of improving the water-supply of the town. The report, which was submitted in the following month, outlined a scheme which was estimated to cost Rs. 2,50,000, and the annual working charges including pumping were reckoned at Rs. 10,000. Plans and estimates in detail were prepared in November 1893, and the scheme was sanctioned by Government in June 1895. The works were completed two years later under the direction of Mr. J. A. Jones, M.I.C.E., late Sanitary Engineer to the Government of Madras, and were formally opened by Sir Arthur Havelock, the then Governor of Madras, in December 1897.

OLD WATER-SUPPLY.

Prior to the introduction of the present water-works, Conjeeveram derived its supply from wells and dug tanks, the latter being replenished by river water by a system of supply inaugurated about 125 years ago. This ancient work is worthy of mention as an example of a public work executed under the sway of the native rulers, before British rule was established in this country. It is the only water-supply work executed during the older *regimés* of which there is any record in this Presidency. The work is primitive in character as compared with modern water-works, but, when it was constructed about a

century and a quarter ago, it ranked as a work of great public utility, and an inscription was set up to perpetuate its completion. The inscription proclaimed that the channels constructed for the water-supply of the town were to be maintained, and certain instructions as to the apportionment of the supply for irrigation and town use were to be attended to, as long as the sun and moon endure. Such was the lack of provision of the achievements of modern science.

The old supply was derived from the Vegavathi, on the left bank of which the town of Conjeeveram stands. In the sandy bed of the river, some distance above the town, a basin is excavated close to the bank. The subsoil water percolating into the basin is conveyed in an open channel to a point in the high ground at the north-west extremity of the town, where the channel terminates in a cistern. From this point water was distributed to the various stone-built tanks in the town by means of underground masonry conduits. The spring basin and channel are still in existence and serve the purpose of irrigation, but the masonry conduits are out of repair and choked up with earth, and fell into disuse some years before the advent of the present works. The remains of the conduit were met with when laying iron pipes for the new works. It was built partly with radiating bricks and partly formed of granite prisms bored to the diameter of the conduit.

PROPOSED IMPROVEMENT OF OLD SUPPLY.

Shortly before the investigation of the present water-supply of Conjeeveram was undertaken, the Engineer to the Local Fund Board of Chingleput had submitted proposals for improving the old water-supply. His scheme was to re-construct and extend the conduit system, with this difference, that instead of utilising the water for filling tanks it was proposed to provide a number of wells with sealed bottoms over the conduit throughout its entire length; and water was to be drawn by dipping buckets or vessels as in ordinary wells. It was pointed out that, whereas the function of the old system merely amounted to the dilution of large bodies of water of a doubtful character in tanks with fresh water from the river, the new proposals would render a supply of water available to the inhabitants in its pristine purity. The scheme apparently promised a solid and substantial measure of improvement, and appealed to the orthodox section of the community, which preponderates in Conjeeveram, and which was opposed to any radical innovation. There was, therefore, some difficulty in proving to the Councillors, that the proposal fell short of modern sanitary requirements, and that a water-supply equipped on modern lines would confer incalculably greater benefit on the inhabitants.

The remarks on this proposal, contained in the author's original report on the Conjeeveram water-supply, will not be considered uninteresting even at the present time, as the system of distribution by masonry conduits and dip wells is still occasionally advocated on grounds of economy, and as an inevitable compromise under certain circumstances. Not many years ago the system found advocacy even in the town of Madras, and in certain remote parts of Madras, where pressure had been reduced to below the level of the taps, the expedient of running the pipe into a well and

drawing water therefrom in the ordinary way was adopted. Fortunately, the Sanitary Commissioner condemned the system and its further extension was prohibited. The arrangement is indefensible from a sanitary point of view. A frequent source of contamination of well and tank water is the introduction of dirty vessels. Cholera germs are often conveyed to drinking water-supplies in this way. It is not unusual to see a woman, going on the errand of fetching water, stop on the way and lay down her burden by the side of the road or some spot still more unclean. If that spot happens to be infected with a cholera patients dejecta, a contingency which is by no means improbable, the vessel subsequently introduced into a well or tank might contaminate the whole supply, for, the cholera bacillus is a micro-organism which multiplies with marvellous rapidity in certain favouring media. During May, one of the driest months in the year, when the supply of water is least abundant, there is a large influx of people who flock to attend the grand festival. The danger of contamination is augmented when a vast concourse of people of all sorts and conditions are allowed to bring their pots and vessels directly in contact with the water-supply.

The following is the extract from the original report referred to above :
 "In discussing the question of conduit wells *versus* pipes and taps, I have entered into particulars which perhaps do not strictly pertain to a professional report, but I have thought it necessary to do so, because I have been told that, in a place which is regarded with such religious veneration as Conjeeveram, modern abominations like pipes and taps will not be viewed with complacency by the higher class of Hindus. Conjeeveram is the most sacred city in the south of India, and has long been the head-quarters of Brahmins. The question of water-supply for such sacred cities is not purely an engineering one, but is also closely associated with such circumstances as caste prejudice and habits of the people. There need, however, be no apprehension about the ultimate universal use of pipe water, if introduced into Conjeeveram, by all classes. At first the higher class of Hindus, especially the Brahmins, may hold off, but as has been the experience in other towns where pipe water has been introduced they are ultimately reconciled to it. This is naturally so owing to the facility of procuring water in a piped system and its comparative purity. These two circumstances are sufficient to overcome the most deep rooted prejudices." The above anticipations have been fully realised. The popularity of the water-supply with all classes in Conjeeveram is now beyond question.

PRESENT WATER-WORKS.

Brief description.—The works as they exist at present may be briefly described as consisting of an infiltration gallery across the bed of the Vegavathi, from which water is pumped by engines and delivered into the town by iron-pipes with their necessary appendages. There is a masonry reservoir, at one of the highest points in the town, which serves as a compensating tank. The noticeable features of the scheme are the peculiarity of its source of supply and the method of collection adopted.

Source of supply.—Though the Vegavathi is called a branch of the Pálár, there is a tradition current in the town that it is the old course of the Pálár itself, which was artificially diverted many centuries ago. There is inherent evidence in substantiation of this belief. (1) The position of the Vegavathi in relation to the main stream suggests the probability of the former stream being the old course of the Pálár. Throughout its entire course of 15 miles the Vegavathi runs nearly parallel to the Pálár, the greatest distance between the two not exceeding two miles at any point. All the other branches of the Pálár diverge from the main stream at a much greater angle. (2) In the neighbourhood of Conjeeveram, the Vegavathi is about 1,000 feet broad. The water which comes down the Vegavathi consists of the overflow from the Damal tank, which is fed by a channel from the Pálár, and the land drainage intercepted by the Vegavathi itself. The combined volume of the two sources of flow in the Vegavathi does not adequately account for the great width of the stream. The highest flood in the Vegavathi seldom attains a height of over 4 feet. These facts lead to the surmise that the stream must have, during some previous period of its existence, carried a greater volume of water than it does at present. (3) It was ascertained, by excavation and probing during the construction of the works, that the bed of the river consists of pure large grained sand to a depth of 30 feet. The sand probably extends to a greater unascertained depth. It is only in large rivers carrying a great volume of water that such a depth of sand is found. This is *prima facie* evidence in support of the belief that the Vegavathi is the old course of the parent stream and not a tributary of the Pálár.

As is usual with rivers in Southern India, there is no surface flow in the Vegavathi for most part of the year, but there is always a copious underflow in its deep sandy bed. The river bed has a fall of 9 feet per mile, and the sand is pure and large grained. An abundant supply of water must, therefore, be travelling through the pores of the sandy bed at a considerable velocity. There are more tangible proofs of the copiousness of the underground flow. There issue from the bed of the Vegavathi six spring channels, which derive their supply from the subsoil flow in the river. The channels irrigate in the aggregate about 1,000 acres of land, and abstract about 1,500 cubic feet of water per minute. The maximum requirement of the town, for which the works are designed, is 188 cubic feet per minute.

The above facts and observations lead to the conclusion⁶ that the Vegavathi was an adequate source of supply and that there was no necessity to go to the Pálár river itself, which would have removed the headworks some two miles further, with proportionate increase in cost.

Supply provided.—When the scheme was prepared, the population was 42,548. The pilgrim population on festival days exceeds 40,000, in view of which, it was considered necessary to provide for a supply in excess of the requirements of the permanent population. The works are designed for a population of 56,000 at 15 gallons per head per day.

All the larger water-works in this Presidency, with the exception of the Madras City Water-works, are designed for a supply of 15 gallons per head per

day. The supply was limited to this allowance owing to financial exigencies, but it was assumed that the works would require enlargement at the end of 30 years to satisfy the needs of an increased population and the demands for a more liberal rate of supply. Some of the earlier works have now been in existence for 20 years, but by the restriction of house-services and the vigilance exercised by the Assistant Sanitary Engineers in checking waste, the consumption has not reached the maximum provided for in any of the schemes. Nearly all of these towns are devoid of any system of drainage, and the stagnation of waste water everywhere would neutralise the benefits of a more liberal supply at present.

Location of infiltration work.—The location of the infiltration work in the river bed received careful consideration. The contamination of a river, which is dry for the greater part of the year as in Southern India, is a more serious matter than the contamination of a river with a perennial flow. It is, therefore, advisable to place the offtake well above the town. On the other hand economy is a matter of paramount importance in designing water-works for Indian towns. The site which seemed to fulfil both requirements, *i.e.*, purity of supply and economy, was the one opposite the Jain temple situated in the village of Tiruparattikundrum, well above that portion of the river which is contaminated by the town. The water supplied to the town has the reputation of being one of the healthiest in the Presidency.

Description of infiltration work.—The infiltration work is simple in design. It was formed by cutting a trench in the bed of the river to the required length and depth, in which open jointed stoneware pipes were laid and the trench refilled with broken stone and sand. This method is very economical, but it is not suited to any river with a sandy bed liable to be disturbed by high floods. The highest flood in the Vegavathi has not exceeded 4 feet and the bed is practically stable at the depth at which the infiltration work lies.

The work is practically a prism of broken stones, 560 feet long, 8 feet broad and $7\frac{1}{2}$ feet high, placed across the river. The top of the prism is level with the lowest ascertained summer water level in the river, which is 10 feet below the bed. The whole of the prism is thus in permanently saturated sand. In the bottom of the prism are four rows of 9-inch stoneware pipes, laid with open joints, and terminating in a chamber close to the margin of the river, from which water is carried by an 18-inch iron pipe to the suction-well on the bank of the river. The end of the pipe in the suction-well is controlled by a valve.

Suction-well and Engine-house.—It will be noticed that the suction-well is placed outside the engine-house. This was done for weighty reasons. The site on which the engine-house stands consists of pure sand extending to as great a depth as in the river itself. In such soil it is difficult to render the bottom of the well water-tight and continuous pumping sometimes develops leaks through the concreted bottom, the evil results of which are manifested by the settlement of the floor and cracks in the walls of the engine-house. In firm and compact soil there is no necessity for detaching the suction-well,

The pumps are connected with the suction-well outside by long suction-pipes the horizontal divergence of which is 50 feet. There has been no trouble attributed to the long suction.

Pumping Machinery.—The pumping engine consisted of two sets (room was provided in the engine-house for a third set) each capable of pumping in 24 hours the whole supply required for 56,000 people at 15 gallons per head per day. The engines were of the horizontal, compound, direct-acting Worthington, non-condensing type, and boilers of the locomotive type.

Reservoir.—The reservoir is not near the engine-house. It is practically at the end of the main where the highest point available in the town is. The reservoir acts by receiving the surplus at times of low demand, and surrenders it when the demand exceeds the capacity of the engines. A service-reservoir close to the engine-house would have been more advantageous, but, owing to the level of the ground near the engine-house and the nature of its soil, the cost would have been great. Experience with *cul de-sac* reservoirs has, however, lead to the conclusion, that a service-reservoir close to the engine-house is worth the larger expenditure involved.

The reservoir is a masonry structure wholly above ground, with the exception of the foundation. The internal dimensions are 71 feet $\times$ 47 feet, with an effective depth of 10 feet. The roof is supported by the four main walls and cross walls 10 feet apart, pierced with large openings to minimise space, and is formed of jack arches 5 feet in span, turned between parallel rows of rolled steel girders. It is believed that this is the first reservoir which has been roofed in this manner. It is the prototype of the design subsequently adopted by the author in the Madras Water-works.

The cost of the reservoir was Rs. 21,111. or Rs. 113 per thousand gallons stored.

Distribution system.—The distribution system as originally laid consisted of 16 miles of cast-iron pipes from 3 to 16 inches in diameter, with their usual fittings and accessories. Eighty per cent. of each size of pipe had turned and bored joints and 20 per cent. plain spigot and faucet joints. This has been the invariable practice in this Presidency. The turned and bored joints have given no trouble owing to leaks as they are reported to have done elsewhere, and they are of course much cheaper than lead joints.

Cost and Capital.—The cost of the works as executed was as follows :—

			Rs.
Infiltration Works ...	...	...	17,582
Pumping Station ...	...	...	20,408
Pumping Machinery ...	...	...	22,591
Reservoir ...	..	...	21,111
Pipes and Fittings ...	...	...	1,39,391
Laying and Jointing Pipes ...	...	...	27,867
Establishment, &c. ...	...	...	8,424
		Total ...	<u>2,57,374</u>

The capital for the construction of the works was provided by Government, one-half as a free contribution and the remainder as a loan repayable in 30 years at $4\frac{1}{4}$ per cent. interest. The sinking fund is 1·7 per cent.

Concluding Remarks.—Some of the details given above indicate the general practice and principles adopted in Madras in the design of water-works. Mr. J. A. Jones, the late Sanitary Engineer, and after him Mr. W. Hutton, have attempted to make the works in this Presidency as far as possible to a standard pattern, and, as is well-known, standard patterns tend to economy both in first cost and repairs.

The holding of a Sanitary Conference annually in India has suggested the possibility of standardising many of the materials used by Sanitary Engineers throughout India. It is suggested that at subsequent Conferences a day or two be devoted to this subject by all the Sanitary Engineers and Municipal Engineers assembled. There are obvious advantages in standardising certain materials, like pipes and fittings as they have all at present to be obtained from England. Pipes and fittings form the largest item in water-works. In the Conjeeveram Water-works, the value of pipes and fittings was 60 per cent. of the cost of the whole work.

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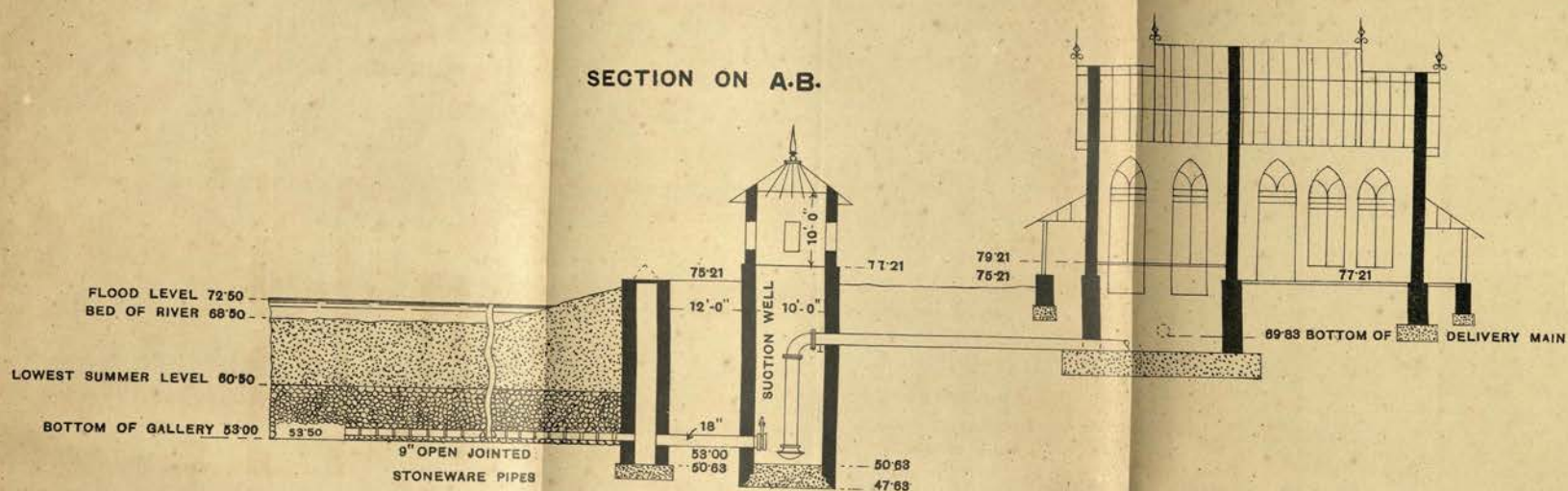
MADRAS,
November, 1912.

THE WATER-WORKS OF CONJEEVERAM.

PLAN OF HEAD-WORKS

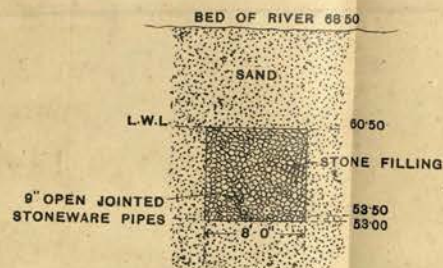
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SECTION ON A-B.



ENLARGED SECTION

SCALE 1 INCH = 10 FEET



PLAN

